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TABLE OF CONTENTS

Vol. 24 August, 1941 No. 8

THE JOURNAL

Phosphates in Ceramics: II, Role of Phosphorus in Bone China 245–47
By W. A. Weyl

Calcium Oxide as a Set-Up Agent for Acid-Resisting Enamels 248
By George Sirovy and E. P. Czolgos

Cause of Pinholes and Some Related Defects in Enamel Coatings on Cast Iron 249–53
By C. A. Zapffe and C. E. Sims

Discussion by G. H. Spencer-Strong 254
Reply by C. A. Zapffe and C. E. Sims 254–56

Summary of Work on Atomic Arrangement in Glass 256–61
By B. E. Warren

X-Ray Study of Soda-Lime-Silica Glass 262–64
By J. Biscoe

Cord Analysis 264–70
By J. C. Turnbull and L. G. Ghering

CERAMIC ABSTRACTS

20—8

Abrasives 187
Art and Archeology 188
Cements 189
Enamel 189
Glass 191
Structural Clay Products 194
Refractories 194
Terra Cotta 196
Whiteware 197
Equipment and Apparatus 199
Kilns, Furnaces, Fuels, and Combustion 200
Geology 201
Chemistry and Physics 203
General 205

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PHOSPHATES IN CERAMIC WARE: II, ROLE OF PHOSPHORUS IN BONE CHINA*

By Woldemar A. Weyl

Abstract

Based on the behavior of phosphates in silicate melts, a possible picture of the constitution of bone-china bodies is presented. The characteristic features are the formation of fluorapatite and hydroxyapatite as the chief constituents of the rigid framework and of a glass high in lime having a higher refractive index than the glassy matrix of normal porcelain bodies. The translucency, the whiteness, and certain characteristic defects of bone china may be explained on this basis.

I. Introduction

In the field of whiteware, English or bone china is another ceramic product[1] in which large quantities of P_2O_5 are introduced. This ware is distinctly different from the rest of the continental porcelain as it contains calcium phosphate as a chief constituent. It was developed by potters in England and until the present time its manufacture has been limited to that country. According to Wood,[2] the use of bone ash dates back to 1750, when a patent was taken out for the use of calcined bones in porcelain bodies. Many of the potters in the Staffordshire area probably made trials with this new ingredient. The credit, however, of perfecting bone china as it is made now must go to Josiah Spode. After years of experiments and failure, in 1794 Spode drew from his kiln the first piece of English bone china, pure white and sparkling in its translucent beauty.

Whiteness and high translucency are the characteristic features of this ware. The manufacture of bone china is extremely difficult even in comparison with the other hard European porcelain. Introducing nearly 50% of bone ash, a nonplastic material makes the body lose much of its workability; the body, in addition, contains china clay and Cornish stone, the latter being a natural mixture of flint, feldspar, and some clay. The ware shrinks tremendously during firing, and it is very sensitive to overfiring. If the temperature rises slightly above the maturing point, it causes the ware to form bubbles and cavities and to assume a spongy structure. Another defect which causes a loss to the manufacturer is the tendency to go off color. The composition range in which pure white colors may be obtained under proper conditions is extremely small.

Despite some serious effort to determine the role played by calcium phosphate, the constitution of bone china is not yet well understood. The aim of this paper is to apply the present-day knowledge, especially on the formation of apatite crystals in bone-ash opal glasses, to this subject and to present a possible picture of the action of phosphorus in this ceramic product. On the basis of apatite formation in bone china, the characteristic properties and defects may be understood.

In the first study of this series,[1] silicate melts, magmas as well as glasses, were shown to have a strong tendency to form minerals of the apatite group whenever phosphates are introduced into melts that contain such divalent oxides as calcium oxide. In the presence of fluorine or chlorine, the fluorapatites or chlorapatites are formed, but if no fluorine or an insufficient amount of fluorine is available, OH groups take the place of the fluorine and hydroxyapatite crystallizes out. Its stability is so great that at temperatures below about 1400°C. it does not lose its water.

In the ordinary whiteware body consisting of feldspar, flint, and clay, feldspar acts as a flux, melting first and acting as a solvent for the other constituents. The solvent action of course is slow because the viscosity of the melt is very high. There is complete agreement that the addition of small amounts of bone ash to such a body increases the fluxing action of the feldspar, which is not unusual considering that bone ash contains about 15% of calcium carbonate, which is known to be a powerful flux in ceramic bodies. Edwards[3] concluded that bone is a flux when it is added to a china body in amounts up to 15%. Such a mixture makes an extremely fusible body, and ware made from it loses its shape completely when it is fired at regular china biscuit temperature. Jackson,[4] to exaggerate this effect, carried out experiments at temperatures somewhat higher than usual. Starting with a mixture of 50% of china clay and 50% of Cornish stone, he introduced increasing amounts of bone ash by replacing equal parts of these two constituents. This series was continued until a mixture of 25% of china clay, 25% of Cornish stone, and 50% of bone ash had been reached. From cone deformation studies, he agreed with the conclusions of Edwards that a mixture containing 15% of bone ash and 42.5% each of china clay and of Cornish stone has the lowest fusion range. Watts,[5] in a comprehensive paper on the effects of bone ash in whiteware bodies, also found that bone ash does not act as a flux at low temperatures (cone 6), but at cones 8 and 10 the body shows a decided tendency to grow softer.

These few observations might be sufficient to show that a part of the bone ash must react with the other

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 3, 1941 (White Wares Division). Received February 3, 1941.

[1] W. A. Weyl, "Phosphates in Ceramic Ware: I, Opal Glasses," *Jour. Amer. Ceram. Soc.*, **24** [7] 221–25 (1941).

[2] H. E. Wood, "Bone in English China," *Trans. Ceram. Soc.* [England], **1**, 21–25 (1901).

[3] H. W. Edwards, "Bone as a Flux in English China," *ibid.*, **3**, 32–36 (1903–1904).

[4] W. Jackson and A. D. Holdcroft, "Fluxing Effect of Bone in English China," *ibid.*, **4**, 6–23 (1904–1905).

[5] A. S. Watts, "Bone China Bodies," *Trans. Amer. Ceram. Soc.*, **7**, 204–31 (1905).

constituents, especially the feldspar, and take part in the formation of a glassy matrix. What is the role of the excess bone ash? The crystals formed in bone china unfortunately are too small to be identified by the petrographic microscope. Two outstanding attempts have been made to investigate the structure of bone china, but the authors did not come to a definite conclusion.

In his work on the constitution and microstructure of porcelain, Klein[6] examined a thin section of a specimen of English bone china. He found that it was composed almost entirely of isotropic inhomogeneous material, consisting of two substances, both extremely fine grained and intimately intergrown. The refractive index of one substance was approximately 1.53 and that of the other approximately 1.61. The material with the lower refractive index resembled the glassy phase found in ordinary vitrified feldspar-clay-quartz bodies.

Cronshaw[7] made a microscopic examination of some experimental samples of bone-china mixtures and he, too, mentions the large amount of isotropic material present as well as the small size of the crystals. According to his findings, the matrix is crowded with ill-defined microlites which barely react on polarized light and which have straight extinction. The nature of the crystals, however, was not revealed.

II. Constitution of Bone China

From these observations and from the general behavior of phosphates in silicate melts, it is concluded that bone china consists of a glassy phase, relatively rich in calcium oxide, which accounts for the relatively high refractive index. In addition to minor amounts of quartz and mullite, probably the chief crystalline constituent is apatite and possibly a mixture of fluorapatite and hydroxyapatite. During the preparation of the slip and the firing, there is no doubt that some of the apatite introduced as bone ash is subjected to a change into hydroxyapatite. This assumption agrees with the findings of Klein and Cronshaw. Apatite forms crystals of low birefringence, and the thin crystals might easily be mistaken for isotropic material. Because the mineral also contains some magnesia, its refractive index probably is lower than 1.63.

The possibility that the relatively small amount of fluorine nevertheless plays an important role in the constitution of bone china has been mentioned by Jackson.[4] In a discussion on Wood's paper,[2] Jackson stated that the substitution of calcium phosphate for bone ash has the same effect on the translucency but that the ware has a greater tendency to deform during firing. He suggested, as a possible explanation, that the small amounts of fluorine might have had an appreciable effect on this property.

From the present point of view, it is known that fluorine helps to build up the rigid framework of apatite crystals, whereas in normal glasses or enamels, it is known to be one of the most powerful fluxes. It takes part in the formation of crystals with an extremely high melting point when it is introduced into a melt that contains both phosphates and divalent ions.

III. Translucency of Bone China

The high translucency is one of the most characteristic and desirable properties of bone china. Experimental evidence as well as theoretical reasoning shows that the translucency of a whiteware body is the result of three main factors, namely, (1) degree of vitrification, (2) difference of refractive indices of the glassy and crystalline phase, and (3) the absorption of light caused by such impurities as iron compounds; in addition, the size of the crystals formed exercises a minor effect. The influence of the constitution of the bone china on these three factors will be discussed here.

(1) The degree of vitrification, that is, the amount of glassy matrix formed, is important when samples of different firing treatment are compared. The translucency increases rapidly with the amount of glass formed but a definite limit is reached in a comparison of different bodies above which it is not safe to go. The solution processes must not be allowed to continue so far that the rigidity of the solid skeleton is impaired. Only rough estimates may be obtained on the absolute amount of glass formed, but the difference in vitrification between ordinary porcelain and bone china probably is not so great that it can exercise a deciding role in the appearance and translucency of the bodies.

(2) The second factor is more important, that is, the difference in refractive indices of the glassy matrix and the crystalline phases embedded in the glass. The refractive index of the glassy phase in ordinary porcelain is about 1.48 as an average value; that of quartz is 1.54; and that of mullite, 1.64. Mullite immediately is seen to be the chief source of opacity, whereas the influence of quartz must be considerably smaller, and this agrees with practical observations. In bone-china bodies, a glassy phase of considerably higher refractive index must first be considered. Because of the high lime content, the refractive index reaches a value of 1.53 (as determined by Klein[6]). The body, however, contains, in addition to the quartz, a considerable amount of apatite, the refractive index of which is certainly lower than that of mullite. The change in constitution from both sides therefore works toward a closer similarity of refractive indices of glassy and crystalline phases.

(3) The translucency of a whiteware body obviously is greatly impaired if the glass or the crystalline phases contain impurities which cause some light absorption in the glassy phase proper.

Bodies to which phosphate has been added show a definite advantage in this respect over those that contain no bone ash. This point will be discussed separately because it leads to the second characteristic property of bone china, namely, its whiteness.

[6] A. A. Klein, "Constitution and Microstructure of Porcelain," *Bur. Stand. Tech. Paper*, No. 80 (December 8, 1916).

[7] H. B. Cronshaw, "Microscopic Study of the Bone China Body," *Trans. Ceram. Soc.* [England], **17**, 153–58 (1917–1918).

IV. Whiteness of Bone China

In addition to the influence of bone ash on translucency, the increase of whiteness or the bleaching of the color caused by iron compounds may be considered to be the other typical property of bone ash as a constituent in whiteware bodies. Most of this effect is undoubtedly caused by the phosphate present in the glassy phase.

Part of the bone ash, as has been shown, participates in the fluxing effect of the Cornish stone, or, more exactly, of the feldspar. The glass formed is therefore high in lime and also contains some phosphate. The reason why P_2O_5 has a bleaching effect on the iron color of glasses will be discussed in a later paper of this series. It is sufficient to point out here that there are heat-absorbing glasses which are colorless but which absorb the near infrared part of the spectrum because of their iron content. This phenomenon is evident only in glasses containing a considerable amount of P_2O_5. The fact that the higher oxide of iron forms colorless compounds with phosphoric acid is well known in analytical chemistry.

The bleaching caused when phosphates are introduced in ceramic bodies has been reported by different workers in this field. In his work on bone-china bodies, Watts[8] noticed how increasing amounts of bone ash cause the bluish tint to disappear so that the color changes to a creamish white. Parmelee[8] studied the influence of phosphoric acid which he introduced in the form of aluminum phosphate. In doing so, all possible changes caused in a ceramic body were excluded when a strong base, such as calcium oxide, was introduced. No difference was seen in the effects on color between bone ash and aluminum phosphate, and both compounds had the same bleaching effect on the iron color. In addition to this effect of phosphates in glasses, there is also a possibility that, even in the crystalline state, iron compounds that are colorless might be formed. The colorless hydrous ferrous phosphate, for instance, occurs in nature as the mineral, vivianite.

V. Characteristic Defects of Bone China

The high price of English bone china is due partly to the high degree of craftsmanship required to manufacture this ware and partly to certain typical defects which cause considerable loss. Discoloration in the decorating kiln results in the most serious loss. Moore[9] described this defect and stated that the main cause seems to be an improper balance between the alumina and the alkali content of the body; a decrease in the amount of Cornish stone, which contains the alkali in the form of feldspar, or an increase in the clay content leads to brown ware. Yates and Ellam[10] made a special study of the color development in the triaxial field, that is, bone ash, china clay, and Cornish stone. Trials were fired to cone 9 in the regular china biscuit oven, and the resulting colors were plotted into a ternary diagram. There are distinct fields of brown and green and bluish shades, but it is difficult to relate the color logically to the composition. Mellor[11] stated that there is only 1% or 1½% of iron oxide in the bone china, but this amount behaves in a very queer way because it forms iron phosphates. He compares the discoloring of the ware with that of the vivianite mineral. This hydrous ferrous phosphate, which is colorless when it is mined, assumes a bluish color when it is exposed to the oxygen of the air and, on prolonged exposure, it becomes covered with a brownish red crust. The bluish color, therefore, seems to be due to the first step of oxidation. Exactly the same process seems to go on in a bone-china body, where a bluish shade is first developed and brownish specks are formed under oxidizing firing conditions. Mellor found bluish crystals covered with a red crust in thin sections, and he emphasizes the fact that this oxidation can take place at low temperatures. Cases are known of brown specks that were not noticeable when the ware was drawn from the kiln but became visible at room temperature.

Another characteristic defect is the spongy structure caused by overfiring. Mellor,[11] who was interested in the manufacture of bone china, was puzzled by the observation that the ware showed an enormous contraction in the first stages of firing but it started to expand rapidly when it was only slightly overfired. An examination with a low-power microscope revealed the formation of gas bubbles, but the origin of these gases still remains a question.

The substitution of OH groups for fluorine and the formation of hydroxyapatite were discussed in Part I of this series.[1] This compound was found to be extremely stable, and the water content was unchanged below 1400°C. At this temperature, the apatite lattice breaks down and complete destruction results. The odor of phosphorus sometimes observed in closed containers when bone china is drawn from the kiln probably is the result of the reduction of the phosphates after the stable apatite has been destroyed.

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[8] C. W. Parmelee, "Action of Phosphoric Acid in Body Mixtures," *Trans. Amer. Ceram. Soc.*, **8**, 236–43 (1906).

[9] Bernard Moore, "Cause and Prevention of Brown Stain in China Bodies in the Enamel Kiln," *Trans. Ceram. Soc.* [England], **5**, 37–44 (1905–1906).

[10] W. H. Yates and H. Ellam, "Study of the Bone China Body: I, Color," *ibid.*, **17**, 120–22 (1917–1918).

[11] J. W. Mellor, "Recent Research on the Bone China Body," *ibid.*, **18**, 497–509 (1918–1919); abstracted in *Jour. Amer. Ceram. Soc.*, **3** [5] 429 (1920).

CALCIUM OXIDE AS A SET-UP AGENT FOR ACID-RESISTING ENAMELS*

By George Sirovy and E. P. Czolgos

Abstract

A study was made of the effect produced by calcium oxide in the set, color, luster, texture, and acid resistance of white and colored enamels.

I. Introduction

Calcium oxide is a white or amorphous substance which melts[1] at 4658°F. and is slightly soluble in water (1 part in 500). It is often used as a component of acid-resisting frits, and a small amount, used as a mill addition, will produce a slip which has a good set.

Ammonium alum, ammonium carbonate, calcium chloride, calcium oxide, and sodium aluminate were added to white, black, blue, green, yellow, red, and brown acid-resisting enamels to examine their comparative values as setting-up agents. The set of the enamel slips and the color, luster, texture, and acid resistance of the fired enamels were observed and compared.

II. Procedure

Samples (500 cc.) of each enamel were milled in 1-gallon jar mills to a fineness of 2 to 3% on a 200-mesh sieve. The white enamel, a white opaque frit, was milled with Vallendar clay 6%, tin oxide 6%, water 40%, and some set-up material. The black and royal blue sample enamels were milled with Vallendar clay 6%, water 40%, and an amount of set-up agent. The medium blue, green, yellow, red, and brown enamels were milled with Vallendar clay 6%, color oxide 4%, water 40%, and an amount of the set-up agent. The amount of each of the set-up materials used, except the calcium oxide, was 0.25%; only $^{5}/_{64}$ of 1% of calcium oxide was needed to produce a good set.

The test plates used were 4- by 6-in. 18-gauge; each enamel was sprayed at a dry weight of 35 gm. per sq. ft. The wet enamels were dried quickly on an electric hot plate and fired individually for 3 minutes at 1520°F. in a Hoskins No. F.H. 204 electric furnace. After twenty-four hours, the enamels were given a 10% citric acid spot test.

III. Observations

(1) Set, Appearance, and Acid Resistance

The degree of set of each enamel slip was noted 24 hours after milling. This was determined by the pattern of the enamel coating that was deposited on the enameled test plate by dipping. A well-set enamel will deposit a uniformly thick, homogeneous coating after the draining is completed. A poorly set enamel will deposit a ripply, orange-peeled coating, consisting of thick and thin drain deposits.

The fired enamels were examined for color, luster, smoothness of surface, and such imperfections as dimples, pits, shorelines, and scum.

The degree of etch, caused by the 10% citric acid spot test, was also noted.

IV. Results

The effects of the setting-up agents produced in the colors tested are as follows:

(1) Ammonium alum produced a good set and it had no effect on the degree of acid resistance. A grayish cast was noted on the royal blue and a haziness occurred in the luster of the black, blues, greens and red. Shorelines were found in the black, blues, brown, and yellow.

(2) Ammonium carbonate produced a good set, and it did not affect the degree of acid resistance. Neither the luster nor the shade of colors was impaired. Dimples appeared in the surface of the white and blue colors.

(3) Calcium chloride produced a good set, and the degree of acid resistance was not affected. A gray cast was noted on the reds, and the greens showed a slight bluish cast. The luster was unchanged, and the surface appearance showed no detrimental effects.

(4) Calcium oxide produced a good set. A small amount, approximately 0.005 of 1%, was added directly to several of the enamel slips to note its setting action. An immediate quick setting up and thickening of the enamel slips occurred, which indicated that its setting-up action is good when it is used for resetting purposes. Calcium oxide effected no change in the degree of acid resistance, and it did not impair the luster, change the shade of color, or cause any defects in the enamel surface.

(5) Sodium aluminate produced a good set, and the degree of acid resistance was unchanged. A gray cast was produced on the blacks, which also showed a decrease in their luster. No defects appeared on the enamel surface.

V. Conclusions

A relatively small amount of calcium oxide is required for setting-up purposes. Powdered calcium oxide may be added directly to the enamel slip for resetting when it is necessary. Because calcium oxide does not affect the degree of acid resistance, impair the luster, change the color, or produce any pits, dimples, shorelines, or scum, it may be recommended as a satisfactory setting-up agent for acid-resistant enamels.

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[1] Handbook of Chemistry and Physics, p. 127. Published by the Chemical Rubber Company.

CAUSE OF PINHOLES AND SOME RELATED DEFECTS IN ENAMEL COATINGS ON CAST IRON*

By C. A. Zapffe and C. E. Sims†

Abstract

The confusion in identifying hydrogen as the predominating cause of certain defects in enamel on cast iron has been due largely to the close association of carbon and hydrogen in cast iron and steel. The principal relation of carbide and graphite to enameling defects is the release of hydrogen from the carbon during enamel firing. The much-discussed "chill layer" therefore is important chiefly because this layer often contains hydrogen that is bound to the carbon in the cementite. Experiments show that when hydrogen is absent, regardless of the depth or nature of the surface chill, no pinholing or blistering results during firing at 725°C.

Sources of the hydrogen that causes the defacement are found chiefly in melting and in casting. The low oxygen pressure of molten cast iron favors hydrogen absorption. Moisture in the atmosphere, in the charge, or chemically combined in the rust on scrap provides the greatest quantities of the gas, and moisture and organic materials in the mold are also prolific sources of hydrogen for absorption by the iron. At ordinary temperatures, rusting is often harmful.

Flushing the melt with a dry, hydrogen-free gas, such as nitrogen, removes the dissolved hydrogen, and defects during subsequent enameling will not occur unless hydrogen is obtained later from other sources.

Chipping phenomena probably are caused chiefly by hydrogen effusion, just as are analogous defects in sheet-steel enameling.

I. Introduction

The cause of pinholing and chipping phenomena in vitreous enamel on cast iron has been debated for many years without satisfactory conclusion just as have the causes of analogous defects in vitreous enamel on steel.[1] The defects themselves have been eliminated fairly well in modern practice, but the remedies for the most part have been developed empirically; as a result, one of the principal causes of defaced coatings has remained unidentified.

Pinholing, the equivalent of blistering in sheet-steel enameling and plainly the result of a boiling action during firing, is probably the most harmful defect in cast-iron enameling. The most widely accepted theory to explain pinholing seems to be the carbon oxide theory, which states simply that carbon oxide gases are formed during firing by the oxidation of the carbon in surface layers of the iron and that the evolution of these gases is mainly responsible for the boiling action. This theory, according to some investigators, also implies that the active surface layer responsible for the gas evolution is a layer of "microchill," which breaks down during firing to provide carbon that is unusually active.

A similar carbon oxide theory has been widely accepted in sheet-steel enameling, but recent work has shown (1) that much of the blistering and boiling action is due, not to carbon oxide gases, but to hydrogen that effuses from the steel during firing and (2) that many fish-scaling and chipping phenomena similarly are caused by subsequent effusion of the hydrogen from the steel at temperatures where the enamel is rigid.[1-7] The gas, in all cases, causes the defects by effusing from the steel and accumulating under the more or less impermeable coating to develop pressures that are sufficient to blister or to chip the enamel. There are many reasons therefore to believe that the analogous defects occurring in cast iron have the same origin.

An extensive review of the literature on defects in cast-iron enameling has been presented[1] and the agreement between recorded observations and the hydrogen theory is so remarkable that this paper should be consulted. The following experimental work is designed

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[1] C. A. Zapffe and C. E. Sims, "Relation of Defects in Enamel Coatings to Hydrogen in Steel," *Jour. Amer. Ceram. Soc.*, **23** [7] 187–219 (1940); discussion, [10] 291–300.

[2] C. A. Zapffe and C. E. Sims, "Hydrogen in Steel and Cast Iron and Defects in Applied Coatings," *Metals & Alloys*, **13** [4] 444–47; [5] 584–89; [6] 737–42; **14** [1] (1941).

[3] C. A. Zapffe and C. E. Sims, "Hydrogen, Flakes, and Shatter Cracks," *Metals & Alloys*, **11** [5] 145–51; [6] 177–84; **12** [1] 44–51; [2] 145–48 (1940).

[4] C. A. Zapffe and C. E. Sims, selected bibliography on "Hydrogen in Steel," containing 500 references, Bibliofilm Document No. 1255; may be obtained from Bibliofilm Service, U. S. Dept. of Agriculture Library, Washington, D. C.

[5] C. A. Zapffe and C. E. Sims, "Defects in Weld Metal and Hydrogen in Steel," *Welding Jour.*, **19**, 377-s–95-s (1940).

[6] C. A. Zapffe and C. L. Faust, "Metallurgical Aspects of Hydrogen in Electroplating," *Proc. Educ. Sess. Amer. Electroplaters Soc.*, **28**, 1–25 (1940).

[7] C. A. Zapffe and C. E. Sims, "Hydrogen Embrittlement, Internal Stress, and Defects in Steel," *Amer. Inst. Min. Met. Engrs. Tech. Pub.*, No. 1307, 37 pp. (Feb., 1941).

to demonstrate the hydrogen theory for defects in cast-iron enameling.

II. Hydrogen as a Cause of Pinholes

(1) Experimental Procedure

To demonstrate the relation of the action of hydrogen in cast iron to its effect on vitreous enamel coatings and to isolate the cause of pinholing and similar defects, 15-lb. heats of enameling iron, composed approximately of C 3.70, Si 2.35, Mn 0.70, and P 0.65%, were made in clay-graphite crucibles in an induction furnace under conditions that will be described later. Subsequent analyses showed that no significant changes in composition had occurred.

The iron was poured at about 1450°C., each heat being split among three types of molds as follows: (1) chill molds of bolted steel plate; (2) molds of natural sand with a permeability of 20, a compression rating of 5.0 p.s.i., and a moisture content of 7½%; and (3) dry molds of silica brick, surfaced with Alundum and dried at 875°C. Each type of mold produced from 4 to 6 specimens, approximately 3½ by 3 by ¼ in. in size.

Both leadless and lead-bearing enamels were used. The mill charge for the leadless enamel was as follows: porcelain balls, 3500 gm.; leadless frit, 1500 gm.; purified clay, 75 gm.; tin oxide, 75 gm.; magnesium carbonate, 4 gm.; and water, 530 cc.

The material left a residue of 4.5 gm. per 50 cc. of slip on a 200-mesh screen after it was milled for 8 hr.

The leaded enamel was composed of lead-bearing frit, 1500 gm.; purified clay, 75 gm.; tin oxide, 75 gm.; and water, 400 cc. It was milled until 2.8 gm. of residue remained from 50 cc of slip on a 200-mesh screen.

The enamels were wet-sprayed, 30 to 50 gm. (dry enamel) per sq. ft., dried at 120°C., and fired for 10 to 20 minutes in an electric furnace at 725°C. The leaded enamel, which is more fluid than the leadless, was generally fired at about 715°C.

(2) Hydrogen Absorption During Ordinary Melting

All of the melts were charged with a certain type of pig iron* except where a substitution of scrap is noted. Heats were made in the ordinary manner to find the extent of blistering following the use of this iron. Chill-cast plates developed varying degrees of pinholing or blistering (Fig. 1).

(3) Iron Containing Hydrogen

According to earlier studies, the bubbles and pinholes appearing on the specimen in Fig. 1 resulted from hydrogen in the cast iron. Pig iron may contain great quantities of hydrogen,[3] and because this quantity varies, the pig from a particular heat may become characterized as "blistering" or as "nonblistering" iron. The present irons, which were made in an induction furnace, would tend to be low in hydrogen because induction melting favors minimum retention of the gas. Severe defects consequently did not occur, nor do they occur in industry when care is taken in melting.

FIG. 1.—Typical chill-cast specimen made under ordinary melting conditions; fired with leadless enamel; occasional pinholing.

To find how greatly the enamel defects could be increased by increasing the hydrogen content of the iron, a melt was made through which hydrogen was bubbled for 15 minutes before it was cast. The hydrogen theory, it will be recalled, states that hydrogen absorbed during melting will be largely retained during pouring and solidification and that liberation of this hydrogen during subsequent enamel firing will cause the defects that are being discussed.

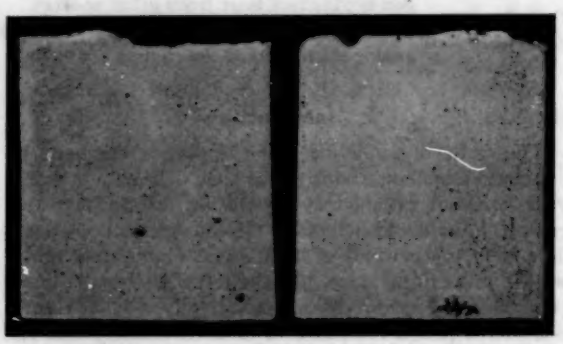

FIG. 2.—Chill-cast specimens of iron melted under hydrogen, fired with vitreous enamel at 725°C.; (*left*) 10 minutes, (*right*) 18 minutes; severe pinholing.

Figure 2 shows two typical chill-cast plates from this melt, fired 10 and 18 minutes, respectively, in which the hydrogen has acted just as was predicted. The results were the same, whether the leaded or leadless enamel specimens were used. Effusion of hydrogen from the iron during firing caused bubbling and blistering; when the blisters broke, pinholes remained; and specks resulted when the iron was exposed to oxidation through the ruptured blister. Discoloration in the form of specks also seemed to be caused by graphite on the surface. The enamel "boiled down" noticeably with increased firing time because the hydrogen ultimately either escaped or dissolved in the iron.

The plates in Fig. 2 show conclusively that hydrogen in cast iron is one cause, and a severe cause, of enameling defects.

(4) Iron with Hydrogen Removed

Judging from work with vitreous enamel on steel and from a review of the literature on cast-iron enameling carbon oxide gases probably have little to do with blistering phenomena at temperatures where "reboiling"

*This pig iron, called "blistering iron," was obtained through the courtesy of the National Bureau of Standards.

occurs, and hydrogen not only may be one cause of enamel defects but it may be the principal cause. The effect of hydrogen could easily be isolated in the present study because this gas may be removed almost completely from molten iron or steel by bubbling a hydrogen-free gas through the melt. The low pressure of hydrogen in the bubbles causes dissolved hydrogen to precipitate and to escape with the other gas.

A melt therefore was made through which carefully dried nitrogen was passed continuously for 15 minutes before it was cast to remove hydrogen that had entered from the charge and to prevent further absorption from the atmosphere. It could be safely assumed from metallurgical studies[2-7] that no appreciable quantity of hydrogen remained in the melt at the time of casting.

The heat was cast in the customary manner, and the castings were enameled. The two typical chill-cast plates in Fig. 3* show the surprising results that were obtained. No blistering or pinholing whatsoever occurred on any of the nitrogen-treated plates. A duplicate melt was made and similar results were obtained. From these tests, it seems necessary to conclude that hydrogen was the only gas present to cause pinholing and blistering.

*Cast-iron specimens often show surface irregularities that should not be confused with the enamel defects under consideration. No attempt was made to remove these irregularities for they are inconsequential to the thesis.

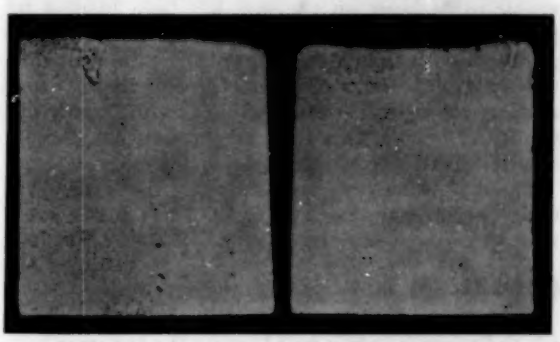

FIG. 3.—Chill-cast specimens made identical to those in Fig. 2 but with hydrogen removed; (*left*) 10 minutes, (*right*) 18 minutes; all blemishes are irregularities on the surface of the iron; no pinholes.

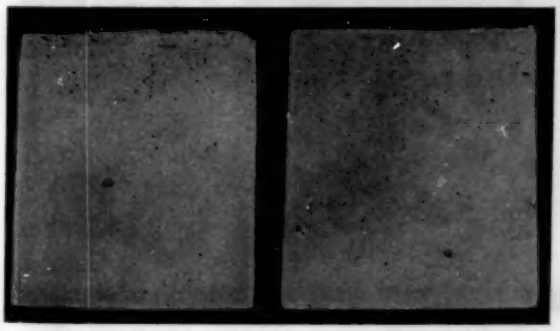

FIG. 4.—Chill-cast specimens of iron made with 20% of scrap; (*left*) no treatment, pinholes; (*right*) flushed with nitrogen, no pinholes.

It must be recognized that the enamels used in this research were fired no higher than 725°C.; higher temperatures would favor carbon-oxygen reactions. The fact remains, however, that no defects appeared in the enamel coatings of the present tests when hydrogen had been removed from the iron.

Castings from these melts were broken and examined micrographically, and it was found that both the hydrogen- and the nitrogen-treated castings had distinct layers of chill in the chill-cast and green sand-cast specimens. The hydrogen-containing castings showed a chill layer that was several-fold thicker than in those containing no hydrogen. This observation conforms to the present theories of hydrogen-carbon activity and corroborates the work of Boyles,[8] who found that hydrogen favors retention of cementite. According to much of the literature on the relation of microstructure to enamel defects, the chill layer in the nitrogen-treated casting should also have caused blistering. Among the several dozen plates enameled there were all degrees of chill, but none developed blisters or related defects when hydrogen was absent.

(5) Effect of Scrap Addition

Tests thus far have indicated that hydrogen is the only gas necessary to consider in the control of pinholing and allied phenomena in the present type of enameled ware and that the severity of defacement varies with the quantity of hydrogen held in the iron. The goal in enameling cast iron, just as in enameling steel sheet, therefore, is to minimize hydrogen absorption by the iron before firing. The sources of hydrogen[1-7] are many, but they lend themselves to broad classifications such as (1) melting practice, (2) casting conditions, and (3) enamel firing. The last-named source, which has been discussed elsewhere,[1-2] will be effective principally after the first coat has been applied, that is, in chipping and reboiling phenomena.

During melting, hydrogen may be introduced through the pig iron, but it is introduced principally through moisture that is contained in the charge and in the atmosphere.[5] Rust on scrap[3] is one of the most important sources of such moisture. The decomposition of this moisture by iron liberates tremendous quantities of hydrogen, and it is particularly significant that the liberation probably occurs inside the melt where all of the hydrogen can be absorbed by the iron. A small amount of moisture may thereby cause greater hydrogen absorption than an atmosphere of the pure gas.[5,7] The deleterious effect of large scrap additions has already been recorded,[1] but until now no explanation has been forthcoming.

To find the relative effect of scrap additions in provoking hydrogen-caused enamel defects, a melt was made in which the charge comprised 12 lb. of pig iron and 3 lb. of scrap. One half of the melt was cast, and the

[8] (*a*) A. Boyles, "Influence of Atmosphere and Pressure on Structure of Iron-Carbon-Silicon Alloys," *Metals Tech.*, 6 [April], 20 pp. (1939).
(*b*) A. Boyles, "Freezing of Cast Iron," *Trans. A.I.M.M.E.*, **125**, 141–203 (1937).
(*c*) A. Boyles, "Formation of Graphite in Gray Iron," *Trans. Amer. Foundrymen's Assn.*, **46**, 297–340 (1938).

remainder was flushed with nitrogen before it was cast.

The scrap was not heavily rusted, and no further effort was made to favor hydrogen absorption. The nitrogen flush, of course, was intended to remove dissolved hydrogen. Castings from the two halves of the heat are shown in Fig. 4, and the results agree with those that were predicted.

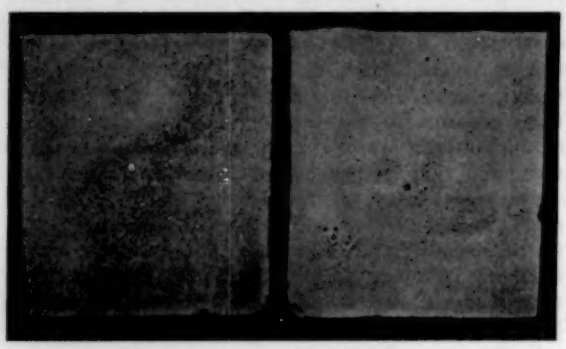

FIG. 5.—Specimens with hydrogen removed but cast in green-sand mold; severe pinholing; (*left*) 10 minutes, (*right*) 18 minutes.

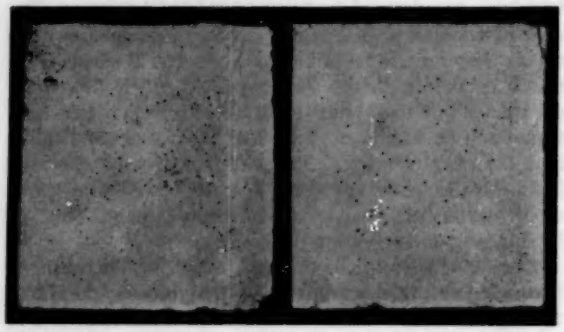

FIG. 6.—Duplicate specimens of Fig. 5 fired with leaded enamel; (*left*) 10 minutes, (*right*) 18 minutes.

(6) Effect of Moisture in Mold

There are numerous reports in metallurgical[3] and enamel[1] literature on definite but generally unidentified relations between moisture or organic material in the mold lining and defects in the cast product. Moisture- or hydrogen-containing compounds, such as oil or cereal, will decompose in contact with hot iron to liberate hydrogen, and the action is shown particularly well in the present experiments.

The nitrogen-treated, hydrogen-free specimens, for example, developed no enamel defects when they were cast against dry, clean molds; when green-sand molds were used, specimens from the same heat developed severe defects (Figs. 5 and 6).

The mold has thus provided moisture or organic compounds to the hot iron, and the resulting absorption of hydrogen is similar to the priming that occurs during the firing of a first coat. The specimen, at least the surface layers, becomes highly charged with hydrogen; when the supplying reaction ceases, the metal has cooled and the hydrogen remaining in the piece in the various conditions already discussed probably will not reappear until subsequent heating.

Rusting, though much slower, is a similar reaction in priming surface layers of iron with deleterious quantities of hydrogen. It is known that castings will blister during firing if they have been allowed to lie around for some time after they are sandblasted.[1] A scarcely visible oxide layer on the iron has been blamed for fomenting a carbon-oxygen reaction, but the much greater quantity of hydrogen absorbed by the iron simultaneously with the formation of the negligible oxide coating is more harmful. Iron absorbs surprising quantities of hydrogen from the atmosphere, the absorption increasing with increasing humidity.

Figure 7 shows a comparison of the generalized severities of enamel defects in chill-cast plates made under various conditions of hydrogen absorption.

(7) Effect of Slow Cooling

Slow cooling creates rather complicated effects relating to hydrogen in cast iron because the specimen is no longer homogeneous; that is, from the standpoint of

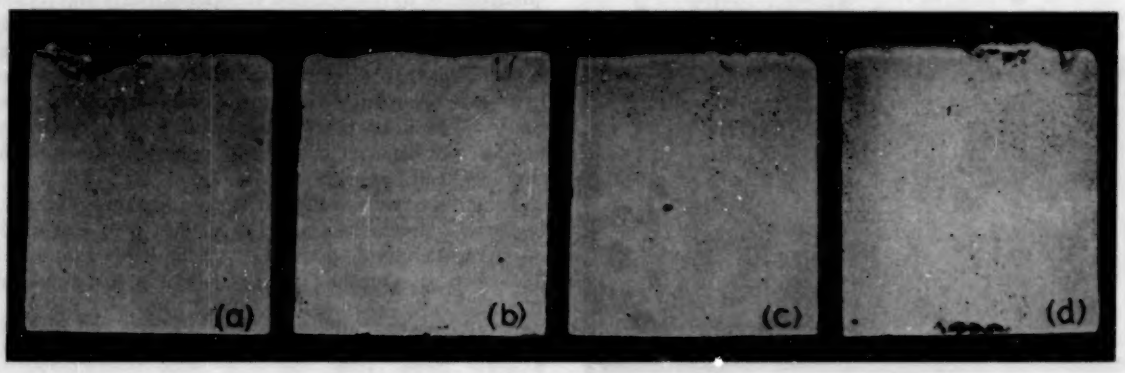

FIG. 7.—Chill-cast specimens prepared under various conditions of hydrogen absorption during melting; fired with leadless enamel at 725°C.; (*a*) nitrogen-treated (no pinholes); (*b*) ordinary melt (occasional pinholing); (*c*) scrap added (significant pinholing); and (*d*) hydrogen added (maximum pinholing). All blemishes on specimen (*a*) are in the iron.

hydrogen absorption, white iron may be considered to be a generally uniform matrix in which hydrogen and carbon are homogeneously associated. Graphitization, however, transforms the matrix into a heterogeneous body consisting of (1) cavities in which hydrogen may occlude molecularly or may react with the graphite and (2) iron, which is ferritic and therefore has a minimum solubility for hydrogen. In graphitized cast iron, hydrogen may thus reside as atoms in the ferrite and as molecular hydrogen or compounds of hydrogen in the internal graphite flakes and inclusions. Incompletely graphitized iron is also complicated by hydrogen which is retained by the carbide in pearlite.

The low solubility of hydrogen in ferrite suggests that slow-cooled or graphitic iron is generally lower in hydrogen content than is white iron. Graphitic irons, however, blister, and this may often be attributed to the hydrogen contained in the flake cavity, for it may be assumed that graphitic iron contains hydrogen in its graphite flakes just as hydrogen is contained in inclusions and cavities. Such hydrogen will redissolve during reheating and may then cause defects by occluding and releasing the hydrogen with the same general effectiveness as inclusions and cavities.[1] Complicating reactions from impurities, which enter the flakes exposed to the surface, must also be considered in an explanation of blistering in graphitic iron.

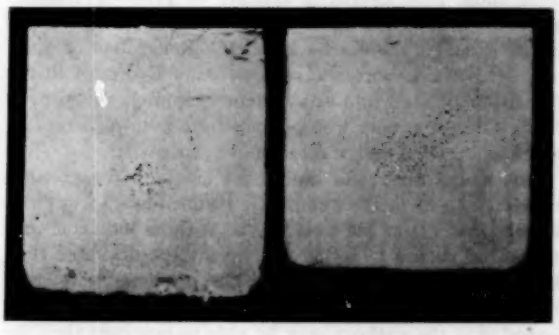

FIG. 8.—Hydrogen-treated, slow-cooled plates fired with leadless enamel for 10 and 18 minutes, respectively; pinholes in center and on edge differ in appearance.

The centers, the slowest cooled portions of the slow-cooled plates, usually developed blisters. Hydrogen-treated plates blistered also over the rest of the surface, although less severely than those more rapidly cooled (Fig. 8).

III. Chipping and Miscellaneous Defects

Chipping and fish-scaling phenomena are not as prevalent in cast-iron enameling as they are in sheet-steel enameling. These defects have been blamed on mechanical stress in both fields. In the case of sheet steel, however, it has been shown that the effusion of hydrogen from the metal base[1] causes fish scales and allied phenomena. Chipping in cast-iron enamel was not investigated in the present research because it bears such an obvious analogy to chipping or fish scaling in sheet-steel enamel.

The fact that chipping occurs less frequently in cast-iron enameling than in sheet-steel enameling should be expected because hydrogen cannot diffuse so readily through cast iron. The usual firing temperatures for wet-process cast-iron enameling, and therefore the solubility of the iron for hydrogen, are also relatively low, and the specimen cannot become as loaded with hydrogen from the moisture reaction as do those fired at higher temperatures.

"Specks" in cast-iron enameling seem to be related to "copperheads" and "black specks" in sheet-steel enameling. They are probably due therefore to oxidation of the iron and are promoted by hydrogen which lifts the enamel off the iron and exposes the metal to oxidation by the atmosphere.

Excesses of oxygen provide a ferric oxide (Fe_2O_3) type of flaw which is characteristically copper colored, whereas restricted oxidation provides ferroso-ferric oxide (Fe_3O_4), the black magnetic oxide. Graphite on the surface also seems to cause specks or discolorations.

IV. Conclusions

(1) Investigations on defects in sheet-steel enameling have been extended to cast-iron enameling, and hydrogen apparently is a predominating cause of blistering and pinholing phenomena during firing in both fields. In fact, in the present tests with enameled cast iron, the occurrence of defects depended only on the quantity of hydrogen in the cast iron.

(2) The carbon oxide theory for blistering and pinholing in wet-process cast-iron enameling is therefore erroneous. The "chill layer," moreover, is important only because the cementite is frequently associated with hydrogen that has been absorbed by the iron. Regardless of the depth or nature of the chill layer, no blistering occurs during firing at 725°C. when hydrogen is absent.

(3) Hydrogen is absorbed from moisture in the atmosphere and in the furnace charge during melting and from moisture and organic materials in the mold during casting. Severe enameling defects may result therefrom, depending on the degree of absorption.

(4) Hydrogen in molten iron may be removed satisfactorily by bubbling dry nitrogen through the melt before casting; no pinholing occurs when this is done if care is taken to prevent subsequent absorption.

(5) It is suggested that the hydrogen retained by cementite probably precipitates in flake cavities simultaneously with the carbon during graphitization and there acts to cause enamel defects during subsequent firing just as does the hydrogen that occludes in inclusions and cavities in steel.

(6) Chipping is less pronounced in cast-iron than in sheet-steel enameling and probably is caused by the effusion of hydrogen from the iron, just as are analogous defects in steel. The mechanical stress theory therefore is probably in error for some types of chipping.

Acknowledgment

Acknowledgment is made to Battelle Memorial Institute for the support of this work as a part of its program of fundamental research and also to D. E. Krause and J. L. Yarne, who conducted the experimental work.

Discussion by G. H. Spencer-Strong

The work of Zapffe and Sims on the effect of hydrogen on cast-iron defects presents an entirely new approach to a subject which has concerned many investigators for a great many years. The fact that their conclusions differ materially from those of earlier investigators is not unexpected inasmuch as a great deal of the work on this subject has been contradictory. Investigators have expressed rather widely differing opinions as to the cause of blistering on cast iron, which has been the major defect encountered in the enameling operation.

The manufacture of enameling cast iron is such a complex problem with so many variables entering into it that it is believed dangerous to attempt to cite any one cause as the reason for cast-iron defects. The behavior of cast iron, however, in small laboratory test samples as compared to that of production ware may be considerably different. Krynitsky and Harrison, for example, report microchill to be a major contributing factor to cast-iron blistering, whereas long experience in the examination of production castings does not show as great a proportion of this type of defect as might be expected.

Zapffe and Sims state that a so-called blistering iron obtained from the National Bureau of Standards was used in their experiments. This, presumably, is the same iron that gave rise to the defects reported by Krynitsky and Harrison. Inasmuch as many foundrymen have reported a direct connection between certain heats of pig iron and the blistering phenomenon and as it has been reported that iron from certain localities is more likely to blister than pig iron from other sources, the pig, apparently, is one of the sources of the difficulty.

The writer, therefore, would like to ask the authors whether they have investigated the amount of hydrogen in the so-called blistering pig. If this has not been done, it would appear to present an excellent opportunity to prove their theory.

The authors have also ignored the effect of the stability of combined carbon on blistering as well as the effect of pouring tempertures. Past experience has shown that the rate of disintegration of the pearlite during the enameling operation has a marked effect on blistering. Experience with commercial irons, furthermore, has shown that a combination of factors is often required to give rise to the blistering phenomenon, and the presence of hydrogen may be one of the major contributing factors. In the enthusiasm of the moment, the work of past investigators should not be overlooked, especially where the work has been substantiated by field experience.

Experiments have shown that the presence of fine graphite on the surface of the iron has a pronounced effect on enameling defects in cast iron and especially on blistering. When enamels are fired in furnaces that lack sufficient oxygen, a considerable amount of graphitic carbon has been found on the surface of the casting under the enamel. This carbon will cause blistering when enamels are applied directly to the iron, or poor adherence may result when ground coats are used. The presence of hydrogen at the enamel iron interface may prevent the oxidation of this graphite and thus give rise to the blistering phenomenon. The writer believes, however, that the graphite, rather than hydrogen, will cause blistering if it is not oxidized.

The chipping phenomenon, at present, causes more loss to the industry than blistering because there has been a tendency to reduce the section of castings, especially in burner grates and there is also a greater tendency to chill than was previously encountered. It is difficult to segregate the physical cause of chill from the causes for the evolution of hydrogen; for example, excess moisture and too tight ramming will give rise to chill in thin-section stove grates, and these are the same factors that contribute to the evolution of hydrogen in the mold. Zapffe and Sims show that hydrogen appears to promote chilling, and excess moisture and insufficient porosity in sand molds should therefore be avoided. Regardless of opinions as to the importance of the role of hydrogen in the formation of chill and subsequent chipping, the proved importance of proper iron composition, pouring temperatures, and casting design should not be forgotten.

The use of mixing or bull ladles has been long recommended as a method to eliminate trapped gases from iron at the cupola, and the work of the authors indicates that the use of such a ladle may be even more desirable than has been thought in the past. The problems that enter into the founding of enameling iron are intricate, and it is hoped that the authors may be able to continue their investigation not only in relation to the effect of hydrogen on enameling iron but also to the numerous other problems which have never been completely investigated or explained.

Porcelain Enamel and Manufacturing Company
Baltimore, Maryland

Reply by C. A. Zapffe and C. E. Sims

No hydrogen analysis of the so-called "blistering iron" was made in the present research for two reasons, (1) analytical procedures for determining hydrogen in iron and steel at present are in such an undeveloped state that their data are often useless and confusing and (2) the fact that hydrogen is the malefic gas is too obvious to question. A method for accurate determination of hydrogen is being developed at Battelle Memorial Institute, and it is hoped that reliable quantitative results can be supplied in future work. From the qualitative standpoint, analyses seem unnecessary.

Analyses, however, have been made by others that illustrate the present argument in spite of the fact that all of the adopted techniques favor underestimation. Thus, whereas enamelers find that large scrap additions and high atmospheric humidity lead to the production of "blistering iron," Schwartz[9] found that cupola-electric white cast iron, made in dry weather, contained about 1 volume

[9] H. A. Schwartz, G. M. Guiler, and M. K. Barnett, "Significance of Hydrogen in the Metallurgy of Malleable Cast Iron," Amer. Soc. for Metals, Preprint No. 3, 21 pp. (1940).

of hydrogen per 3 volumes of metal, but that the hydrogen content in damp weather increased to three times that amount, and an addition of rusty scrap raised that value again to four times the normal amount. Direct analogies in steelmaking are so numerous that there is little reason to doubt that the irregular behavior of cast iron during enameling in regard to blistering is an expression of the hydrogen content of that iron. Enamelers have shown that the amount of carbon oxides given off during firing is unrelated to blistering. In the present studies and in supplementary work,[10] experiments have shown that blistering in enamel on cast iron depends only on the hydrogen content of the iron up to temperatures of 1500°F. or more. Carbon oxide gases undoubtedly form, as has been shown by gas analyses; but the quantities are insufficient in most enamels to produce blistering. A possible factor that contributes to the ineffectiveness of carbon oxide gases to cause blistering is that the enamel may become fluid and permeable at the elevated temperatures where those gases form so that relatively greater quantities are required to deface the enamel. In the viscous range, where hydrogen effusion is pronounced and the enamel is most sensitive to blistering, carbon-oxygen reactions are very slow.

The effect of the stability of combined carbon on blistering has not been ignored in the present work. The mutually stabilizing tendencies of carbon and hydrogen on one another, in fact, have formed the basis for the research. The rate of disintegration of pearlite should be closely associated with blistering because both are affected by hydrogen. Cast iron that contains much hydrogen graphitizes irregularly and slowly, and graphitization is accompanied by a release of hydrogen formerly held by the cementite. Schwartz* found that the hydrogen content of white cast iron may be reduced to one tenth its original value by annealing, and analogies in steel are well known. Schwartz also presents data to show the stabilizing effect of hydrogen on cementite.

RELATION OF HYDROGEN CONTENT AND GRAPHITIZING RATE*

Hydrogen (wt. %) × 10^5	Graphite (%) formed in 4 hr. at 400°C. (750°F.)
20	0.69
25	0.54
30	0.42
46	0.38
50	0.085
58	0.037
64	0.028

* Selected values from Table IX of Schwartz's paper.

At 900°C. (1650°F.), he found that 0.32% of graphite formed in 5½ hours in normal iron. A heat treatment designed to remove hydrogen from this same iron yielded specimens that graphitized 1.68% with the same treatment; when the iron was artificially loaded with the gas, the graphitization fell to 0.05%.

Broad assumptions regarding the effect of pouring temperature, degree of overheating, and such characteristics of cast-iron production cannot be made safely; but it is important to remember that the quantity of hydrogen absorbed and retained by the iron is strongly affected by many of those factors. To blame enamel blistering on some irregularity in the making of the iron may then be entirely correct except that a coincidental happening is being recognized with a neglect of the true cause.

There is an excellent analogy in steel making in the hydrogen-caused defect known as "flakes." Early metallurgists variously blamed flakes on the refining operation, casting temperature, speed of casting, uphill or downhill casting, ingot size, quick heating in the rolling mill, or excessive draft on rolling; it was found recently, however, that hydrogen was necessary for flaking and that all of these coincidental functions were important principally because they affected the hydrogen content of the steel.

The pronounced effect of fine surface graphite on blistering may possibly be a result of the same action that obtains when powdered aluminum metal is added to enamel slip. Both elements are strong deoxidizers and probably react during firing with the moisture remaining in the dried coating. Hydrogen will be liberated by either, but carbon oxide gases may also be formed with carbon. The hydrogen, furthermore, may react with the carbon to form methane. A small addition of aluminum seems to lead to less blistering, but larger additions are inadvisable for several reasons. A small amount probably reacts with the chemically combined water that remains in the dried coating, liberating the hydrogen out of contact with the iron, and depletes itself by that oxidation, whereas a largre amount, leaving free aluminum after the dehydration, would prevent oxidation of the iron and would lead to expected complications. Fine surface graphite may act similarly to aluminum except that a more gaseous product is formed by the carbon reaction and the position of the graphite at the interface would favor blistering from the dehydrating action.

Chipping of enamels on cast iron has not been studied in the present research. Preliminary observations, however, have agreed with the expectation that fishscaling is not common in cast-iron enameling. The chipping, mentioned by Spencer-Strong, may occur on ware that is later heated in service. Heating would promote decomposition of Fe-C-H compounds to liberate hydrogen, but at room temperature not much effusion of hydrogen from cast iron should be expected to occur. Whether the chipping he observes is solely a function of hydrogen or whether dimensional changes in the iron may cause or aggravate chipping cannot be answered at this time. It seems, however, that dimensional changes in the iron should cause fractures resembling hairlining rather than chip-type defects such as are caused by hydrogen.

The authors appreciate Spencer-Strong's remarks for they recognize him as one who anticipated the present work on hydrogen by calling the attention of enamelers several years ago to discrepancies in the carbon oxide theories that were being proposed and accepted by many at that time. Incidentally, in one of his papers,[11] the con-

[10] C. A. Zapffe and C. E. Sims, "Further Considerations of Hydrogen as a Cause of Enamel Defects," to be published later in *Jour. Amer. Ceram. Soc.*

[11] G. H. Spencer-Strong, "Relation of Microstructure to Enamelability of Cast Iron," *Trans. Amer. Foundrymen's Assn.*, **46** [6] 783–810 (1938); *Ceram. Abs.*, **19** [3] 61 (1940).

figuration of the graphite is associated with the tendency toward blistering. If the work of Boyles[8] or Schwartz[9] is consulted, analogous relationships may be found between configuration of the graphite and the hydrogen content of the iron. Spencer-Strong concludes with the statement, "The literature makes no mention of the relation of the pattern of the graphite to enamelability." That is strictly true, but actually the literature contains, perhaps in widely separated recordings, most of the facts needed to derive many of those relations immediately. The principal importance of the present research is that it shows how many of these facts that are ordinarily regarded separately may be used to develop a coherent picture when the behavior of hydrogen in iron and steel is understood.

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SUMMARY OF WORK ON ATOMIC ARRANGEMENT IN GLASS*

BY B. E. WARREN

ABSTRACT

The present picture of the atomic arrangement in glass has developed from four kinds of information, namely, the laws of crystal chemistry, the X-ray diffraction study of glass, the various measured physical properties of glass, and the kinds of materials and the ranges of composition in which glassforming properties exist. X-ray diffraction studies establish the predominant type of bonding in the glass, for example, the tetrahedral bonding in silicate glasses. Secondary structural features such as those which change with annealing or conditioning do not show up in the X-ray pattern. Most of the proposed structures are those which are suggested and are partially substantiated by X-ray studies, those which fit the laws of crystal chemistry, and those which seem best able to explain the physical properties of the glass.

The preliminary theory of immiscibility in glass systems has been extended to include a consideration of the temperature dependence. A study of thermal expansion in terms of the number of glassforming bonds allows a simple correlation between thermal expansion coefficients in the silica–boric oxide and the soda–boric oxide systems. The same kind of considerations used in discussing immiscibility may be used to give a quantitative treatment of the change in the coordination number of the boron atom when boric oxide is present with soda.

I. Introduction

The attempts which have been made in recent years to build up a picture of the atomic arrangement in glass have been dependent almost completely on the earlier X-ray diffraction studies of the structure of crystalline silicates. Relatively little was known before 1925 about the structures or of the laws which determine the structures of either crystalline or glassy silicates. The development began around 1926 with the work of the Bragg and the Pauling schools. During a period of about eight years, complete X-ray structure determinations were made for a large number of complex crystalline silicates. In spite of the variety and apparent complexity of the structures, it was soon evident that all of these structures were determined by a few simple laws, such as the now familiar rule that the silicon atom in all silicates is tetrahedrally bonded to four oxygens at a distance of 1.62 A. The formulation of these laws governing the way in which the atoms are bonded together in silicate structures was the beginning of the modern structural silicate chemistry. An excellent summary of this information has been given by Bragg.[1] All of this work was a necessary basis for Zachariasen's important contribution.[2] He reasoned that the laws which had been found to govern the structures of crystalline silicates must also apply to the silicate glass, and he predicted the random-network type of structure in a glassy material.

The direct determination of the structure of a glass by X-ray diffraction methods was not as straightforward as the earlier work on the crystalline silicates, inasmuch as a glass gives an amorphous type of diffraction pattern similar to a liquid rather than the sharp-line pattern that is characteristic of crystalline materials. The first X-ray work on glass was done by the cut-and-try method, that is, by guessing a structure and then comparing the calculated and observed diffraction patterns. This method was unsatisfactory because it was difficult to say how unique a structure had been determined and it was obviously limited to the simplest of compositions.

The successful application of X-ray diffraction analysis to the structure of glass followed from another development. In 1927, Zernicke and Prins[3] had shown that the radial distribution of atoms in a liquid could be obtained from a Fourier integral analysis of the liquid

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 2, 1941 (Glass Division). Received April 7, 1941.

[1] W. L. Bragg, Atomic Structure of Minerals. Cornell University Press, Ithaca, N. Y., 1937; *Ceram. Abs.*, **17** [6] 231 (1938).

[2] W. H. Zachariasen, "Atomic Arrangement in Glass," *Jour. Amer. Chem. Soc.*, **54** [10] 3941–51 (1932); *Ceram. Abs.*, **12** [4] 145 (1933).

[3] F. Zernicke and J. A. Prins, "Diffraction of X-Rays in Liquids as an Effect of Molecular Arrangement," *Z. Physik*, **41**, 184 (1927).

diffraction pattern. By generalizing this method to make it applicable to materials containing more than one kind of atom, a general straightforward method was obtained for analyzing the X-ray diffraction patterns of glass. The first application[4] of the Fourier method to glass was on vitreous SiO_2 and B_2O_3 and since then practically all X-ray studies of the structure of glass have been made by this method. Radial distribution curves may be obtained directly from the X-ray diffraction pattern without any assumptions as to the structure of the material.

An example is the distribution curve for vitreous silica shown in Fig. 1. The position of each peak in the curve gives the distance between two atoms in the glass, and the number of neighboring atoms at that distance can be determined from the area under the peak. The kinds of atoms whose separation is represented by any peak can be determined only by comparing the distance with the distances of separation found in crystalline materials. The first peak in Fig. 1, for example, is recognized immediately as representing the separation between a silicon and oxygen atom in the glass because the position of 1.62 A corresponds exactly to the silicon-oxygen separation in the tetrahedral SiO_4 groups found in crystalline silicates.

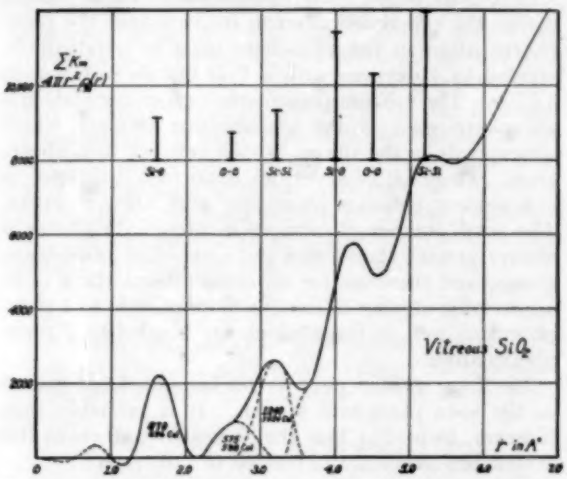

FIG. 1.—Radial distribution curve for vitreous SiO_2, obtained from X-ray diffraction pattern.

The present picture of the atomic arrangement in glass has developed from four kinds of information, namely, (1) the laws of structural silicate and borate chemistry as determined from crystalline studies, (2) X-ray diffraction studies of glass, (3) the various measured physical properties of glass, and (4) the kinds of materials and the ranges of composition in which glass-forming properties exist. It would be incorrect to say that the present random network theory of the structure of glass has been uniquely established. It is preferable to consider it as a picture of the structure of glass which at the present time is best able to correlate and to explain the experimental facts and measurements. No single source of information is capable of establishing the structure of glass. A theory, such as that of the random-network structure for glass, becomes more probable as more kinds of information can be correlated in terms of the theory.

II. Silicate Glasses

Vitreous silica has the composition of SiO_2. Assuming that the laws of structural silicate chemistry apply to the glass, it can be predicted that each silicon must be tetrahedrally bonded to 4 oxygens. In every crystalline silicate that has been analyzed, the silicon atom has been found at the center of a group of 4 oxygens arranged at the corners of a tetrahedron, with the Si-O distance of 1.62 A. The first peak in the distribution curve of Fig. 1 is at the position, 1.62 A, indicating that the silicon-oxygen distance in the glass is the same as in crystalline silicates. The area under the peak indicates that the number of oxygens, at this distance from a silicon, is approximately 4. The X-ray results therefore indicate quite clearly that the same kind of tetrahedral bonding exists in the glass as in crystalline silicates. If each silicon is bonded to 4 oxygens, it is evident from the composition of SiO_2 that each oxygen must be bonded to 2 silicons.

Although the tetrahedral type of bonding in vitreous silica may be assumed to be well established, this does not completely fix the structure because exactly the same kind of bonding is found in all the crystalline modifications of silica. The width of the first strong peak in the diffraction pattern of vitreous silica indicates that the structure is random, rather than one in which there is the identical repetition of a crystalline material. If the glassy silica is assumed to have the cristobalite structure, the width of the peak indicates that the assumed crystals must be too small for the term "crystal" to have any significance. The absence of small-angle scattering in the X-ray diffraction pattern indicates that the glassy structure is continuous without gaps or discontinuities. All of these arguments, which indicate strongly the continuous random network structure of vitreous silica, have been summarized.[5] The simplest picture of the structure of vitreous silica, which seems to fit the experimental facts, is one in which each silicon is bonded tetrahedrally to 4 oxygens and each oxygen is bonded to 2 silicons, the bond forming a continuous random network with no unit of structure necessarily repeating at regular intervals.

In a silicate glass containing alkali or alkaline earth, the total number of oxygens is greater than twice the number of silicons. With each silicon bonded tetrahedrally to 4 oxygens, part of the oxygens must be bonded to 2 silicons and the others only to 1 silicon. From electrolysis experiments and an analogy to the crystalline feldspars, the alkali or alkaline earth atoms

[4] B. E. Warren, H. Krutter, and O. Morningstar, "Fourier Analysis of X-Ray Patterns of Vitreous SiO_2 and B_2O_3," *Jour. Amer. Ceram. Soc.*, **19** [7] 202–206 (1936).

[5] (*a*) B. E. Warren, "X-Ray Determination of Structure of Liquids and Glass," *Jour. Applied Physics*, **8** [10] 645–55 (1937); *Ceram. Abs.*, **17** [2] 87 (1938).
(*b*) B. E. Warren and J. Biscoe, "Structure of Silica Glass by X-Ray Diffraction Studies," *Jour. Amer. Ceram. Soc.*, **21** [2] 49–54 (1938).

are assumed to exist as ions, randomly situated in the holes of the silicon-oxygen network. A schematic two-dimensional representation of the structure is shown in Fig. 2. The X-ray results for simple binary systems, such as soda–silica,[6] agree with this picture. The main features of the structure and the general scheme of bonding can be taken to be definitely predicted by the laws of structural silicate chemistry and to agree with the X-ray results. It should be emphasized that the X-ray study of a glass gives information only on average quantities; it tells nothing about the fine details of the structure and the possibility of small variations in the structure. Secondary structural features, such as those which change with annealing or conditioning, do not affect the X-ray pattern sufficiently to be recognized. The X-ray studies of glass might be said to establish the first order approximation to a picture of the structure, and the fine details must be filled in from other kinds of measurements.

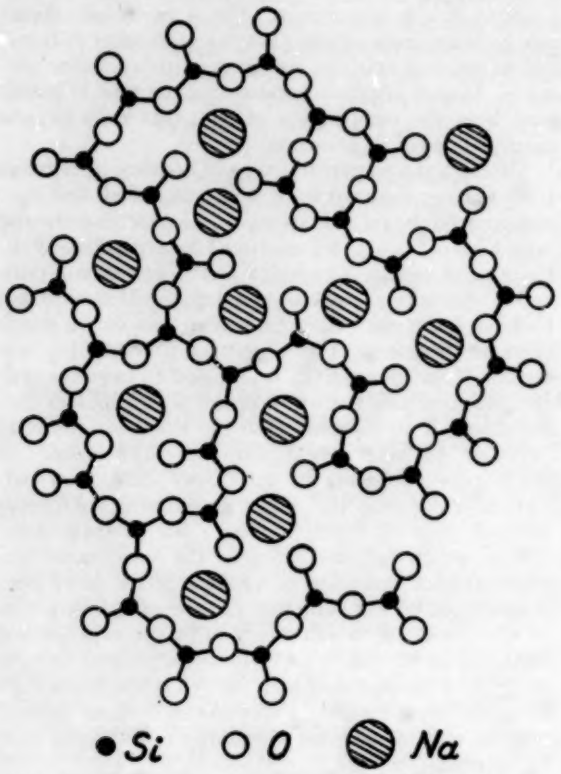

FIG. 2.—Schematic representation in two dimensions of the structure of soda-silica glass.

III. Borate Glasses

X-ray studies on vitreous B_2O_3 indicate a random-network structure in which each boron is triangularly bonded to 3 oxygens and each oxygen is bonded to 2 borons. The structure in the binary system boric oxide–silica consists of a random network in which the silicons are tetrahedrally bonded to 4 oxygens, the borons are triangularly bonded to 3 oxygens, and each oxygen is bonded to 2 cations. The X-ray results cannot establish this structure completely because of the small scattering power of the boron atom, but it is a structure which agrees with the laws of crystal chemistry and it is in keeping with the approximate additivity of specific volumes.

When boric oxide is present in a glass with an alkali or alkaline earth oxide, such as soda, part of the boron atoms may change over from the normal triangular coordination to fourfold-tetrahedral coordination. This change is indicated by the X-ray studies of the soda–boric oxide system[7] and by the anomalous changes in such physical properties as density and thermal expansion. (The theory of this effect will be discussed in more detail in section VI.)

IV. Phosphate Glasses

The phosphorus atom in crystalline phosphates is tetrahedrally bonded to 4 oxygens with a P–O distance of about 1.55 A. An X-ray study has been made of two compositions in the lime–phosphate system.[8] The first peak of the radial distribution curves occurs at 1.57 A, and the area under the peak corresponds to 4.2 oxygens about each phosphorus. These values, within the experimental error, indicate that the phosphorus atom in the phosphate glass is tetrahedrally bonded to 4 oxygens with a P–O distance of 1.55 to 1.57 A. The random phosphorus-oxygen network in a phosphate glass is the glassforming element which corresponds to the silicon-oxygen network in a silicate glass. There is, however, an important difference in one respect between phosphate and silicate glasses. The total number of oxygens in phosphate glasses is always greater than twice the number of phosphorus atoms, and therefore for all compositions there is an appreciable number of oxygens bonded only to 1 phosphorus as well as those which are bonded to 2 phosphorus atoms.

No X-ray studies have as yet been made on glasses in the soda–phosphate system. It is probably safe, however, to predict that the phosphorus atoms in this system are tetrahedrally bonded to 4 oxygens.

V. Theory of Immiscibility

It has been shown that the problem of immiscibility in glass systems[9] can be interpreted in terms of the valence and size of the atoms and also in the possibility of a given composition to provide suitable surroundings for each atom. A rough calculation was made in the earlier report of the limit of immiscibility in the lime–silica system, neglecting the effect of temperature. The calculation will be repeated here to include a quali-

[6] B. E. Warren and J. Biscoe, "Fourier Analysis of X-Ray Patterns of Soda-Silica Glass," *Jour. Amer. Ceram. Soc.*, **21** [7] 259–65 (1938).

[7] J. Biscoe and B. E. Warren, "X-Ray Diffraction Study of Soda-Boric Oxide Glass," *ibid.*, **21** [8] 287–93 (1938).

[8] J. Biscoe, A. G. Pincus, C. S. Smith, Jr., and B. E. Warren, "X-Ray Study of Lime-Phosphate and Lime-Borate Glass," *ibid.*, **24** [4] 116–19 (1941).

[9] B. E. Warren and A. G. Pincus, "Atomic Consideration of Immiscibility in Glass Systems," *ibid.*, **23** [10] 301–304 (1940).

tative indication of the temperature dependence. The equilibrium diagram for the lime–silica system shows that, in certain regions of temperature and composition, the melt segregates into two immiscible phases (Fig. 3).

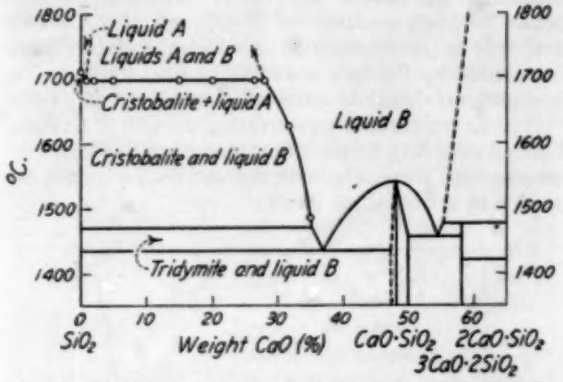

FIG. 3.—Equilibrium diagram of the system SiO_2–$2CaO \cdot SiO_2$ (J. W. Greig).

In a single-phase, lime-silica melt, there will be oxygens bonded to 2 silicons and oxygens bonded only to 1 silicon because the total number of oxygens is greater than twice the number of silicons. The oxygens which are bonded only to 1 silicon are unsaturated, and each Ca^{++} ion tries to surround itself by several of these single-bonded oxygens. Because the number of single-bonded oxygens is twice that of calcium atoms and in order that each calcium shall have a reasonable number of surrounding oxygens, it is necessary for each single-bonded oxygen to bond to more than 1 calcium. Two calciums bonded to the same oxygen cannot be farther apart than twice the Ca–O distance.

$$\text{Ca–Ca} = 2\text{Ca–O} = 2 \times 2.38 = 4.76 \text{ A.}$$

For a homogeneous glass with atoms uniformly distributed, the volume of glass containing 1 calcium atom will be of the order of magnitude of the cube of the linear separation.

$$\text{Vol./Ca} = (4.76)^3 = 108 \text{ A}^3.$$

If the composition is represented as $X\%$ by weight of CaO and $(100-X)\%$ by weight of SiO_2, the volume of 100 gm. of glass will be

$$V_{100} = \frac{100}{\rho} \times 10^{24} \text{ A}^3.$$

The number of Ca atoms in X gm. of CaO is given by

$$N_{Ca} = \frac{X}{56.1} 0.606 \times 10^{24}.$$

The volume of glass per calcium atom in A^3 is then

$$V_{Ca} = \frac{V_{100}}{N_{Ca}} = \frac{100}{\rho} \cdot \frac{56.1 \times 10^{24}}{0.606 \times 10^{24} X} = 108.$$

For the range of compositions of interest, ρ has an average value of about 2.6.

$$X = \frac{100 \times 56.1}{108 \times 0.606 \times 2.6} = 33\%.$$

This means that for compositions in which the lime content is less than about 33%, the Ca^{++} ions and the single-bonded oxygens are too few in number and too widely separated for each to be surrounded by a proper number of the other. For a lime content of less than about 33%, the energy of the single-phase liquid is higher than the energy for a two-phase liquid in which the lime has segregated into one of the phases so as to bring the content of that phase up to 33%.

The behavior of the system is of course determined by the free energy, the system segregating into two phases when the free energy of the two-phase system becomes less than the free energy of a single-phase system. Because this is only a qualitative discussion of free energy, consideration will be given only to an energy difference resulting from whether or not the Ca^{++} ions and single-bonded oxygens have proper surroundings and to a temperature entropy difference for which the entropy difference is essentially the increased entropy of the single phase caused by the entropy of mixing. The three-coordinate diagram in Fig. 4 shows these two differences as a function of temperature and composition.

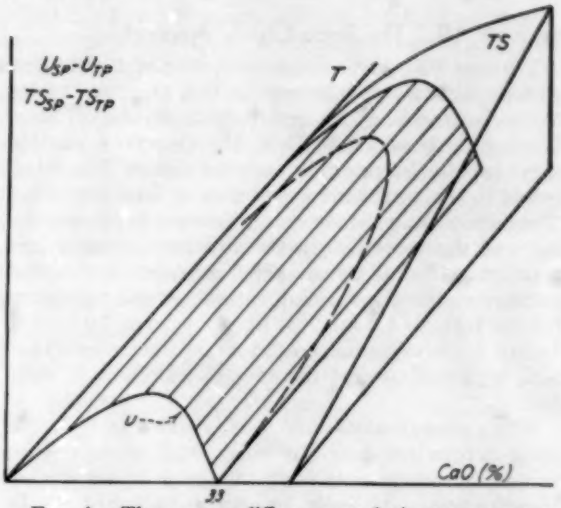

FIG. 4.—The energy difference and the temperature entropy difference which determine the limit of immiscibility in the lime–silica system.

For a lime content of less than about 33%, the energy of the single-phase becomes greater than that of the two-phase system. This is approximately independent of temperature, and the energy difference, $U_{SP}-U_{TP}$, is represented by the tunnel-shaped surface running parallel to the temperature axis. As a result of the entropy of mixing, the entropy of the single-phase is greater than that of the two-phase system. The temperature-entropy difference, $TS_{SP}-TS_{TP}$, is shown by the surface marked TS; it increases proportionally to T for a given composition, and it increases with the percentage of lime* for a small lime content. The line of

* The shape of the TS surface, as a function of composition, is given qualitatively by assuming it to be similar to the curves which have been calculated for the entropy of mixing of two gases.

demarcation between the single-phase and the two-phase region is the line along which the two free energies are equal.

$$F_{SP} - F_{TP} = (U_{SP} - U_{TP}) - (TS_{SP} - TS_{TP}) = 0.$$

This will be given by the intersection of the two surfaces. The form of the intersection is suggested qualitatively by the dotted curve of Fig. 4.

The limit of immiscibility on the high lime side shifts to lower lime content as the temperature increases. Above temperatures corresponding to the peak of the curve, there is complete miscibility for all compositions. The present treatment is not intended to be more than qualitative. The only quantitative calculation involved is the composition 33%, below which the energy of the single phase becomes appreciably greater than the energy of a two-phase system. The approximations involved in the calculation of the composition 33% are sufficiently rough so that the value has no great accuracy. The treatment is not intended to do more than to suggest the nature of the atomic processes which determine the miscibility and immiscibility in a glass system such as lime–silica.

VI. The Boric Oxide Anomaly

Vitreous B_2O_3 has a large coefficient of thermal expansion, because each triangular BO_3 group is bonded to the surrounding structure only in three directions. When SiO_2 is added to B_2O_3, the thermal expansion drops rapidly, inasmuch as each tetrahedral SiO_4 group bonds to the surrounding structure in four directions. The more SiO_2 in the structure, the more bonds per cation and the more tightly the structure becomes knit together. If m is the weighted average coordination number of the glassforming cations, it will vary from 3.0 for B_2O_3 to 4.0 for SiO_2 for the system B_2O_3–SiO_2. In Fig. 5, the expansion coefficient for the system B_2O_3–SiO_2 is plotted against the average coordination number, m.

When a small amount of soda is added to B_2O_3, the extra oxygen introduced by the soda allows part of the borons to change over from triangular to tetrahedral coordination. If each oxygen is assumed to be bonded to 2 borons, the number of borons in tetrahedral coordination can be readily calculated for each soda content. The borons in triangular and tetrahedral coordination have 3 and 4 bonds, respectively, so that the average coordination number, m, can be computed for each composition. The expansion coefficient for the system Na_2O–B_2O_3 is plotted in Fig. 5 against the average boron coordination number, m, assuming that as many borons as possible have changed to tetrahedral coordination at each composition.

The comparison of the two curves is rather striking. Starting from the composition, B_2O_3, the addition of soda produces exactly the same drop in expansion coefficient as the addition of silica, when the compositions are expressed in terms of average coordination numbers. The Na–O bonds are too weak to be of much importance, and the expansion coefficient depends only on the average number of strong cation bonds. The increase in the cation coordination number from 3 to 4 is equivalent, whether it is made by changing a boron atom from triangular to tetrahedral coordination or by replacing a triangularly bonded boron by a tetrahedrally bonded silicon.

The two curves separate sharply at an average coordination number of $m = 3.17$, corresponding to a Na_2O–B_2O_3 composition of 13.0% of Na_2O. This evidently is the composition at which the extra oxygen introduced by the soda ceases to be used up when the boron atoms change to tetrahedral coordination. From this point on, there is an increasing number of oxygens bonded only to 1 boron. The expansion coefficient increases with increasing soda content similar to the behavior in a soda-silica glass.

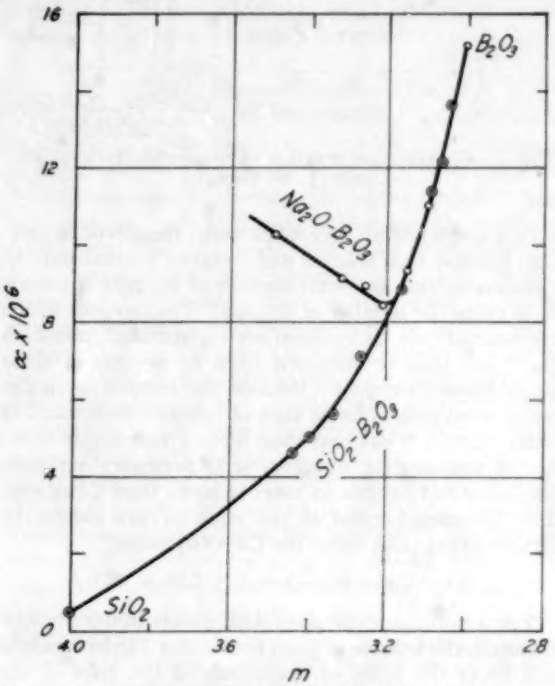

FIG. 5.—Thermal expansion coefficients vs. average coordination number m.

Two questions that immediately suggest themselves are (1) why do as many as possible of the borons change to tetrahedral coordination for small soda content and (2) why does this process stop at a composition of about 13% of Na_2O? The answer is given by the same kind of considerations that have been used in discussing the problem of immiscibility. If a small amount of soda is added to B_2O_3 and all of the borons remain in threefold coordination, there will be two kinds of oxygens, namely, those bonded to 2 borons and those bonded only to 1 boron. The sodium ions, Na^+, will try to surround themselves by the unsaturated single-bonded oxygens. The number of Na^+ ions and of unsaturated oxygens is too small at small soda content, and they are consequently too widely separated for this to be acccomplished effectively. On the other hand, if as many as possible of the borons change to tetrahedral coordination, there will be four times as

many unsaturated oxygens and therefore a much better possibility for the Na^+ ions to surround themselves by unsaturated oxygens. The change takes place merely to produce a structure of lower energy. When the soda content gets high enough for the Na^+ ions and unsaturated oxygens to be present in sufficient numbers to provide suitable surroundings for each other, the need for further change decreases rapidly.

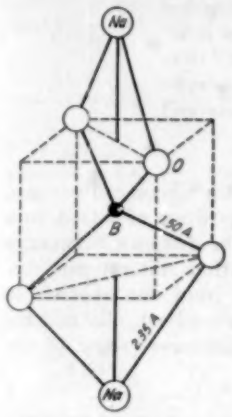

FIG. 6.—The arrangement of Na^+ ions around the unsaturated oxygens of a BO_4 tetrahedral group.

This limiting composition can be calculated with a few simple approximations. Assume that each oxygen is bonded to 2 borons and that as many as possible of the borons are in tetrahedral coordination. Each oxygen in a boron-oxygen tetrahedral group is unsaturated, inasmuch as a trivalent cation B^{+3} has half interest in 4 divalent negative oxygens. Each tetrahedral group, as indicated in Fig. 6, must contact 2 sodium ions to satisfy the unsaturated oxygens (because 1 sodium cannot touch all 4 oxygens). The interatomic distances are

$$B\text{–}O = 1.50 \text{ A and } Na\text{–}O = 2.35 \text{ A}.$$

From the geometry of Fig. 6, the Na–Na distance is calculated as 5.73 A. The average separation of sodium ions in the glass must then be of the order of 5.73 A, and the volume per sodium atom must be of the order of the linear separation cubed.

$$V_{Na} = (5.73)^3 = 188 \text{ A}^3.$$

The composition may be represented as X gm. of Na_2O and $(100 - X)$ gm. of B_2O_3.

In the range of composition of interest, the density has an average value of 2.2 and the volume of 100 gm. of glass is given by

$$V = \frac{100}{\rho} = \frac{100}{2.2} = 45.5 \times 10^{24} A^3.$$

The number of Na atoms in X gm. of Na_2O will be

$$N_{Na} = \frac{(2X) \times 0.606 \times 10^{24}}{62.0}.$$

The volume per Na atom is then

$$V_{Na} = \frac{V}{N_{Na}} = \frac{45.5 \times 10^{24} \times 62.0}{(2X) \times 0.606 \times 10^{24}} = 188.$$

$$X = 12.4\% \text{ } Na_2O.$$

This value should represent the composition at which there is no further need for complete change to tetrahedral coordination. The value is to be compared with the composition of 13% at which the two curves of Fig. 6 separate.

The approximations involved in the foregoing calculation are rather rough, and the excellent numerical agreement therefore is largely fortuitous. The important point is that from these calculations some insight is gained of the significance of the anomalies in the soda–boric oxide system. All extra oxygen introduced by the soda at low soda content is used up in changing boron atoms into tetrahedral coordination to provide better surroundings for the Na^+ ions. There are enough unsaturated oxygens above the calculated composition to provide proper surroundings for the Na^+ ions, and further changing of boron atoms into tetrahedral coordination becomes rapidly unnecessary.

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X-RAY STUDY OF SODA-LIME-SILICA GLASS*

By J. Biscoe†

Abstract

X-ray diffraction patterns of three compositions of soda-lime-silica glass were made, and radial distribution curves for the three glasses were obtained from Fourier analyses of the patterns. The results indicate that the silicon atoms are tetrahedrally bonded to 4 oxygens. Each oxygen is bonded to either 1 or 2 silicons. If each sodium is assumed to be surrounded by 6 oxygens, each calcium must be surrounded by about 7 oxygens. The structure is similar to that of soda-silica glass except that some of the sodiums are replaced by calciums. A qualitative correlation of the structure with density and coefficient of expansion is made.

I. Introduction

The structure of a soda-lime-silica glass would be expected to be similar to that of a soda-silica glass,[1] but in view of the commercial importance of the former, it seemed worth while to examine a few compositions lying in the range of industrial glasses. Three glasses with the following compositions, by weight, were examined by the Fourier integral method‡:

	(1)	(2)	(3)
SiO_2	0.683	0.763	0.694
CaO	0.206	0.124	0.102
Na_2O	0.109	0.114	0.202

II. Experimental

X-ray patterns were made, using samples in the form of a rod about 0.5 mm. in diameter placed at the center of an evacuated cylindrical camera with a radius of 4.38 cm. Calcium fluorescence radiation was eliminated by placing 0.003-in. aluminum foil in front of the photographic film. The incident radiation was MoKα (λ = 0.710 A), monochromatized by reflection from a rock-salt crystal. The films were microphotometered, and the microphotometer readings were converted into intensities. The resulting intensity curves, corrected for polarization, are shown in Fig. 1. Differences among these curves are small, as would be expected, because the silica content does not vary much and the roles played by sodium and calcium are not very different from a structural standpoint.

III. Determination of Structure

The radial distribution curves obtained by Fourier analyses of the intensity curves are shown in Fig. 2. Each of these curves is the sum of four distribution curves, namely, the atoms about a silicon, an oxygen, a calcium, and a sodium. The position of a peak in a curve of Fig. 2 therefore gives the distance between a pair of atoms, provided the various interatomic distances are sufficiently different from one another so that the corresponding peaks are resolved. By making a list of possible interatomic distances, some of the peaks may be identified.

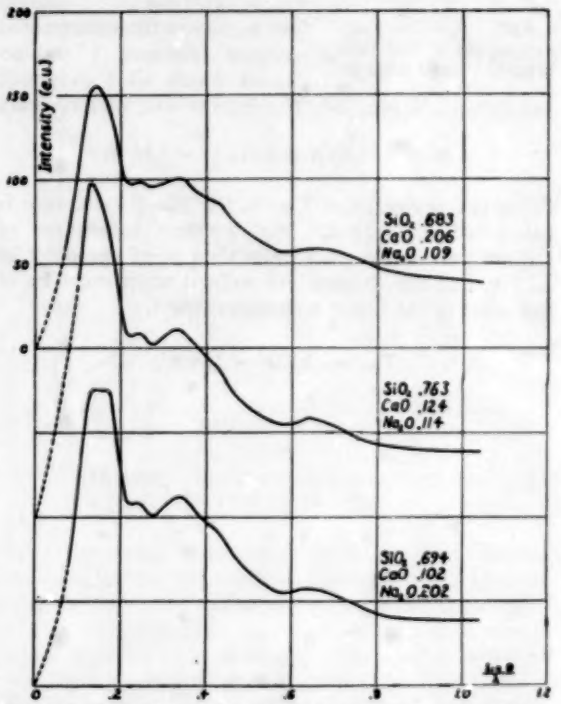

Fig. 1.—Experimental intensity curves of soda-lime-silica glasses.

The following nearest neighbor distances have been found in other glasses[2] and in crystals: Si–O 1.62 A, Na–O 2.35 A, O–O 2.65 A, and Ca–O 2.4 A. The first peak in Fig. 2 is at 1.62 A for all three of the curves. Inasmuch as the curves fall to zero at about 2 A and as

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† Glass Research Fellow.

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[1] B. E. Warren and J. Biscoe, "Fourier Analysis of X-Ray Patterns of Soda-Silica Glass," *Jour. Amer. Ceram. Soc.*, 21 [7] 259–65 (1938).

‡ A. G. Pincus, American Optical Company, kindly furnished samples (1) and (3) with their analyses.

[2] J. Biscoe, A. G. Pincus, C. S. Smith, Jr., and B. E. Warren, "X-Ray Study of Lime-Phosphate and Lime-Borate Glass," *Jour. Amer. Ceram. Soc.*, 24 [4] 116–19 (1941); see also footnote 1.

there are no other interatomic distances less than 2 A, the Si–O distance in all three compositions is 1.62 A. The average number of oxygens about each silicon may be calculated from the area under the peak. The values so obtained, 4.6, 4.6, and 4.8 in the order of increasing lime content, are in poor agreement with the number 4 always found in crystals. The difference is probably due to approximations which must be made in a Fourier analysis. The approximation that the atomic scattering factors may be set proportional to one another becomes worse the greater the difference in the atomic numbers of the atoms in the glass; because of experimental limitation, only that portion of the intensity curve lying between $\frac{\sin\theta}{\lambda} = 0$ and about 1.0 is used. In view of these approximations, it cannot be concluded from a Fourier analysis that the number of oxygens about a silicon at 1.62 A is other than 4. If the number of oxygens bonded to one silicon were greater than 4, the silicon-oxygen distance would be expected to be greater than 1.62 A, because an increase in interatomic distance always accompanies an increase in the coordination number. In the Fourier analysis method, peak positions are more accurate than peak areas. It is concluded, therefore, that each silicon is surrounded on the average by 4 oxygens at a distance of 1.62 A.

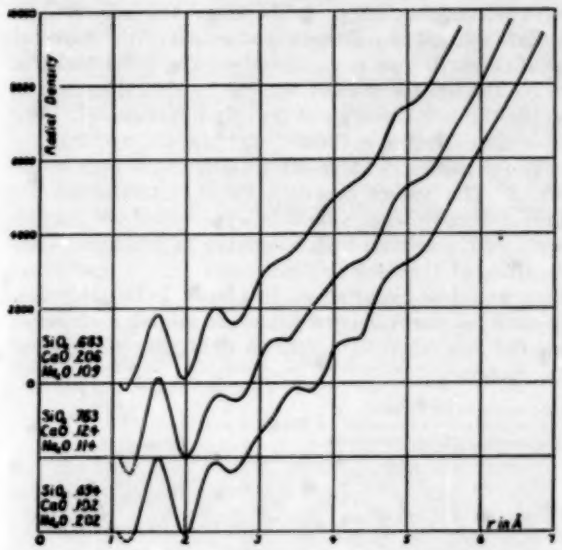

FIG. 2.—Radial distribution curves of soda-lime-silica glasses.

If the Si–O distance is 1.62 A and each Si is assumed to be surrounded by 4 oxygens at the corners of a tetrahedron with the Si in the center, the distance between oxygens of the same tetrahedron is 2.65 A. If it is assumed that as many oxygens as can be are bonded to 2 silicons and that the remainder are bonded to 1 silicon, the number of oxygens about an oxygen at 2.65 A and the area of the corresponding peak may therefore be calculated as a function of composition. Assuming that each sodium is surrounded by 6 oxygens, the area of the Na–O peak at 2.35 A may be calculated. If these two peaks are subtracted from the distribution curves, a peak is left at approximately 2.4 A with an area corresponding to 6.1, 7.0, and 7.3 oxygens about a calcium for the three glasses in the order of increasing lime content. These values are reasonable, but in view of the even greater uncertainty here as compared to

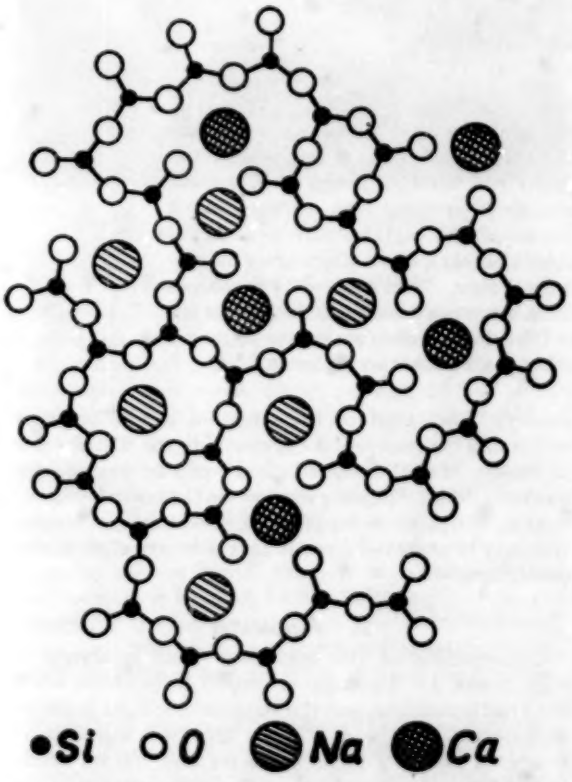

FIG. 3.—Schematic representation in two dimensions of the structure of soda-lime-silica glass.

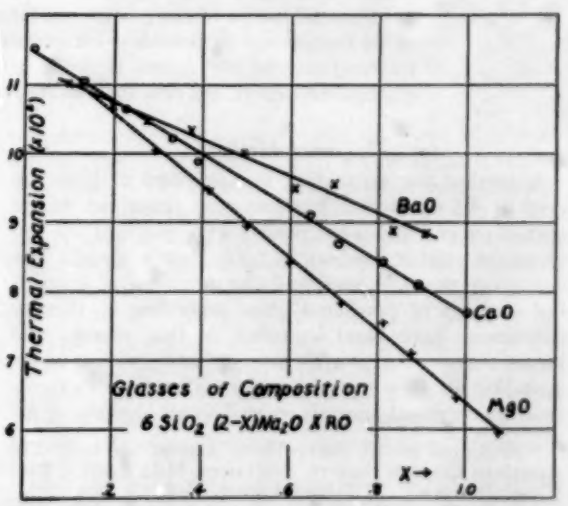

FIG. 4.—Effect on thermal expansion of replacing Na_2O by the indicated oxides (plotted on a molal basis).

the Si–O peak, no significance is attached to the variations in the values.

The next interatomic distance which has a definite value is the Si–Si distance at 3.2 A. There are so many possible indefinite distances in this region, however, that this peak is almost obliterated except in the glass of highest SiO_2 content.

The structure of soda-lime-silica glass is essentially that of soda-silica glass with some of the sodium ions replaced by calcium ions. The silicons and oxygens form a three-dimensional random network in which each silicon is surrounded by 4 oxygens, each approximately at the corner of a tetrahedron. Some of the oxygens are bonded to 2 silicons and some to 1 silicon. There are holes in this random network in which the sodium and calcium atoms lie surrounded by about 6 and 7 oxygens, respectively.

The one unequivocal result of this analysis is the Si–O distance. The other conclusions are in accord with the radial distribution curves, but it cannot be shown that some other structure would not fit the observed curves equally well.

IV. Discussion

The effect on the coefficient of thermal expansion of replacing soda in a soda-silica glass by various amounts of alkaline earths is shown in Fig. 4.[3] The coefficient of expansion is reduced by the addition of any of the oxides and, on a molal basis, the effect is greatest for MgO and least for BaO. The reduction is accounted for by the fact that the divalent alkaline earth ions have stronger electric fields than the monovalent sodium ion. The relative effectiveness of the different alkaline earth ions is explained on the basis that the larger the ion the smaller will be the field due to it in which the neighboring oxygens find themselves. The ionic sizes increase in the order of Mg, Ca, and Ba.

The densities of these same glasses have been measured.[3] The values observed for the BaO series are almost exactly what would be expected if the barium replaced the sodium with no change in structure. The densities of the lime and magnesia glasses run higher than would be expected on this basis, indicating that, because of the stronger fields associated with these smaller ions, there is a general tightening together of the structure.

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[3] G. W. Morey, Properties of Glass, pp. 230 and 233. Reinhold Publishing Corp., New York, N. Y., 1938; *Ceram. Abs.*, **18** [2] 48 (1939).

CORD ANALYSIS*

By J. C. Turnbull and L. G. Ghering

Abstract

Results on the separation of inhomogeneities in bottle glass by density differences have been improved by changes in technique and apparatus. The accuracy of chemical analysis has been increased by taking larger samples for analysis, although they represent smaller fractions of the glass. The new centrifuge is equipped with windows and a stroboscopic light so that the movement of the suspended particles may be observed as the separation takes place. It is thus possible to obtain a curve which gives the distribution in density of the particles of the powdered glass. This curve and the analysis of the fractions of the powder of extreme densities have shown considerable value in the interpretation of the causes of cordy glass. The density distribution curves, composition differences, and case histories of several bottle glass cords are discussed.

I. Introduction

A method for separating fine powders of glass according to density differences was described in an earlier paper,[1] and some results were given of the application of this method to cordy bottle glass. The centrifuge that was used and the technique of separating samples of powdered glass according to density differences have been improved so that cleaner and larger cuts of the powder may be made with a corresponding increase in composition differences as measured by chemical analysis as well as an increase in accuracy. This kind of investigation would be more useful and conclusive if a curve giving the distribution in density of the powdered glass could be found; this has been done by putting windows in the centrifuge head so that, with a stroboscopic light, the process of separation may be observed directly as it occurs in the rotating centrifuge.

II. Apparatus

Construction of the centrifuge head is shown in Figs. 1 and 2. The tube is viewed from above while the head is rotating, and the stroboscopic light is placed underneath the head. There are two windows of tempered glass,† 2 in. in diameter and $^3/_{16}$ in. thick, in the head above and below the tube containing the

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 1, 1941 (Glass Division). Received April 9, 1941.

[1] J. C. Turnbull, "Separation of Inhomogeneities in Bottle Glass by Density Differences," *Jour. Amer. Ceram. Soc.*, **24** [2] 37–43 (1941).

† Courtesy of E. L. Hettinger, Willson Products, Inc.

suspension. The stroboscopic light, General Radio type 631-P1, is fired by a contactor on the centrifuge shaft; there is one contactor for each of the two sets of windows made of a set of Delco Remy high-speed distributor points.

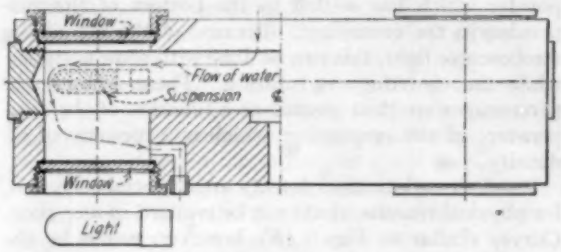

FIG. 1.—Cross-section view of centrifuge head, showing the windows through which the suspension of powdered glass is viewed stroboscopically; stroboscopic light underneath the head; dotted outline is the tube containing the suspension.

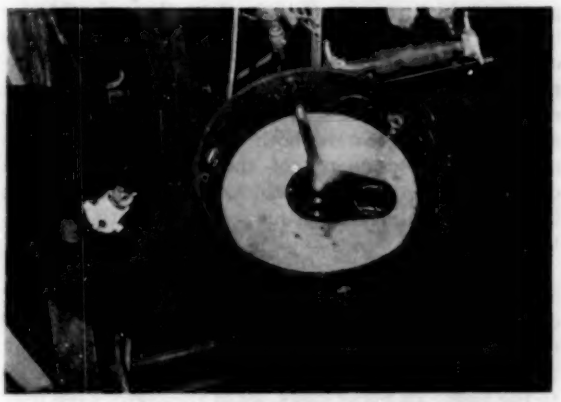

FIG. 2.—Top view of reassembled centrifuge.

III. Method of Separation

Changes in procedure have improved the separation of glass into fractions of the extreme densities. In the first method,[1] the powder was divided into two parts by centrifuging and separated by pouring off the upper fraction. It was later noted that the powder could be arranged on the bottom of the tube according to its density; starting at a high temperature, with the powder all on the bottom of the tube, the temperature is slowly lowered, until all of the powder is on top, then raised, until all of it is on the bottom again. After decanting off the liquid, the powder is removed, and the top portion is taken for the light fraction and the bottom for the heavy fraction. The errors involved, which are not large, may be decreased by fractionation, that is, repeating the separation on the separated fractions.

To test the separation, powders of known inhomogeneity were made by mixing two optical glasses.‡ These glasses differed in density by 0.005 gm. per ml. and in index of refraction by almost 0.001 gm. per ml. The density difference can be decreased to zero by uniform heat treatment,[2] but the index difference remains about the same. Individual particles may be identified by index, using an immersion medium of intermediate index, and the degree of separation may be estimated by counting particles with a microscope.

After one run, made for a density difference of 0.4° C., or about 0.0008 gm. per ml. with 50% of each kind of glass, the glass was divided into four equal fractions. The two extreme fractions showed 99% separation of the glasses and each of the middle fractions showed 80% or more separation. With a small amount of one glass, the separations were not so efficient; at the same density spread, with 5% of lighter glass or 5% of heavier glass, the end fractions showed a separation of about 60%. If, therefore, a small amount of inhomogeneity is to be separated, two runs should be made.

IV. Chemical Analysis of Separated Fraction

Samples taken for chemical analysis were $^1/_2$-gm. cuts, one cut comprising the heaviest part of the powder and one the lightest. These samples represent 5% cuts when the total powder at the start is 10 gm., or 1.3% when 40 gm. are taken. Two additional larger samples, one about 15% of the intermediate light and the other 15% of the intermediate heavy powder, were also usually analyzed in order to follow the composition changes along the density-distribution curve.

TABLE I

PARTIAL ANALYSES ON FOUR FRACTIONS OF GLASS NO. 451

	Check Results on Separation Plus Analysis*			
	Heavy (6%)	Heavy intermediate (18%)	Light intermediate (18%)	Light (4%)
Na_2O	13.21	13.11	12.99	12.92
	13.32	13.23	13.08	12.92
Al_2O_3	1.34	1.33	1.34	1.35
	1.35	1.35	1.34	1.36
CaO	5.54	5.56	5.44	5.46
	5.56	5.49	5.50	5.51
MgO	3.61	3.61	3.65	3.59
	3.63	3.62	3.61	3.61

* Discarded fraction, 44%.

Partial analyses for Na_2O, Al_2O_3, CaO, and MgO were run on the $^1/_2$-gm. fractions. When silica analyses were run on the extreme cuts, duplicate separations were necessary to obtain a total of 1 gm. of material. The typical partial analyses, shown in Table I and obtained on two separations on the same sample, illustrate the reproducibility of the analyses of Na_2O, Al_2O_3, CaO, and MgO on $^1/_2$-gm. samples.

When SiO_2 was run directly, everything except the minor ingredients totaled about 99%. As a further check on the reproducibility and efficiency of the separation and also on the analytical results, the average density difference of the cord was calculated from the

‡ Bausch & Lomb types C-1 and BSC-2.

[2] See the work of Morey and Merwin on the soda–lime–silica system; G. W. Morey, Properties of Glass, p. 242. Reinhold Publishing Corp., New York, 1938; *Ceram. Abs.*, **18** [2] 48 (1939).

composition difference using Huggins' factors,[3] and this value was compared with that taken from the density-distribution curve obtained with the centrifuge.

V. Density-Distribution Curve

Cords in glass have different kinds of composition variations with corresponding variations in density for the powdered glass. If, for example, the scales for weighing the batch are inaccurate and cause random composition variations, the glass production of the tank may have random variations in density. These variations would be described by the normal curve for the distribution of errors, Fig. 3 (*A*), where the curve specifies the number of particles having a particular density within a certain small range of density. A maximum number of particles at a certain density is found here, which is the average density of the glass.

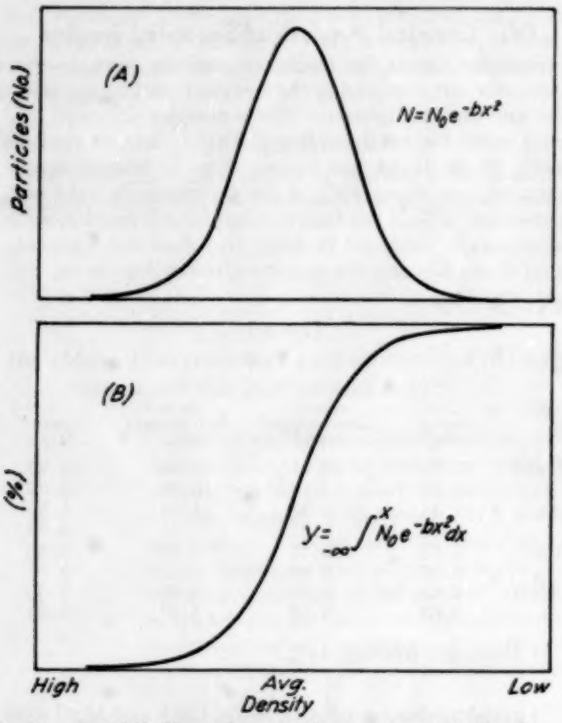

FIG. 3.—(*A*) Normal curve for random distribution of density; (*B*) integral form of normal curve for random distribution of density.

It is more convenient, however, to use the integral form of the distribution curve, where, instead of specifying the number of particles which have a certain value of density within a small density range, the total number of particles having density greater than a certain value is given. For this value of density, therefore, the integral curve gives the area under the first curve taken from very high values of density to the value in question. The integral form for random distribution of variations in density then has the form shown in Fig. 3 (*B*).

The integral form of distribution curve is obtained experimentally by measuring the relative amount of powder which has settled to the bottom of the suspension in the centrifuge. Because of the use of the stroboscopic light, this can be done with some accuracy while the centrifuge is rotating. These amounts in percentages are then plotted as a function of the temperature of the suspension, which is a measure of its density.

Random variations in density are a special case, and, for physical reasons, could not be realized in any glass. Curves similar to Fig. 3 (*B*), however, would be obtained in the foregoing case where batch composition fluctuated in a nearly random manner. Such a curve, obtained from a bottle glass made from batch of varying composition, is shown in Fig. 9. Incomplete melting might be expected to give a similar sort of distribution curve; for example, to the extent that light glass is present, which represents high silica, there should also be heavy glass, which represents low silica, and the noncordy production (if there is any) should have an intermediate composition and density. The distribution curve, in other words, should show variations from the average density toward both high and low densities although the symmetry of the normal distribution curve may be absent. Batch segregation also might be expected to give the same sort of density-distribution curve.

With refractory pick-up, or stir-up of stagnant glass, a different distribution curve may be found. These cords often affect only a part of the base glass, and the remainder may be fairly homogeneous. The cordy part is characterized by the addition of foreign material to the glass; in many cases, all of the cordy glass may be either lighter or heavier than the homogeneous glass, particularly when refractory pick-up results in the addition of silica or a combination of silica and alumina to the base glass.

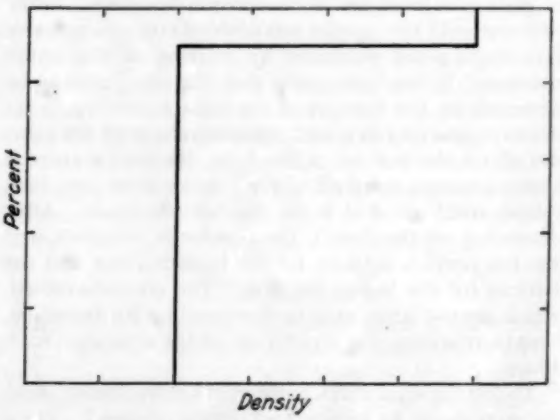

FIG. 4.—Ideal form of distribution curve for a mixture of two homogeneous glasses, representing, respectively, the base glass and the cord.

[3] M. L. Huggins, "Silicate Glasses—Calculation of Densities, Refractive Indices, and Dispersions from Glass Composition," *Ind. Eng. Chem.*, **32** [11] 1433–36 (1940); see also *Glass Ind.*, **22** [5] 228(1941); *Ceram. Abs.*, **20** [2] 42 (1941).

For purposes of illustration, this type of cord may be represented by a mixture of two homogeneous glasses; a large part of the glass has high density, representing the base glass, and a smaller part has low density, representing the cord. At the appropriate value of density, each homogeneous glass will appear as a step in the distribution curve (see Fig. 4).

Approximations to this ideal curve may be found experimentally. The cords themselves, however, are never homogeneous, although the base glass may be. The steep portions of the curve, furthermore, are not exactly vertical because even completely homogeneous glasses would occupy an interval of about 0.4°C. on the experimental curves. Curves, such as those illustrated in Figs. 5 and 8, are therefore obtained under conditions where refractory pick-up was suspected.

Two limiting kinds of cords evidently are found from the distribution curves, one in which all of the glass is cordy and the distribution curve is S-shaped; in the other, part of the glass is homogeneous and all of the cord is heavier or lighter than the base glass. This classification of cords, furthermore, would be expected to have considerable significance, and the distribution curves, together with the results of chemical analysis, should be capable of verifying certain interpretations as to the causes of particular cords in glass. Some of the results obtained on bottle glasses are given in section VI.

VI. Experimental Results

(1) Refractory Corrosion or Addition of Foreign Material

Two similar cords, made in different factories, were found in glasses No. 632 and No. 91. The cord appeared as a heavy streak accompanied by high polariscopic strain in both cases, and the ware showed spontaneous breakage. Both tanks were old; the cord appeared in No. 632 after a patch was applied on the bridge-wall, and the flux blocks at the sides of both tanks were almost eaten through to the outside.

The density-distribution curves for these glasses are shown in Figs. 5 and 6. The homogeneous glass in both cases has a density equal to the heaviest of the powder; No. 632 differs from No. 91 chiefly in having a great deal more homogeneous glass, which was removed from No. 91 when the cord was cut out before the glass was powdered. The form of the distribution curve indicates the addition of foreign material to the glass. The composition changes shown in Table II indicate that the contaminant for No. 632 was largely silica with some alumina; for No. 91, it was mainly silica.

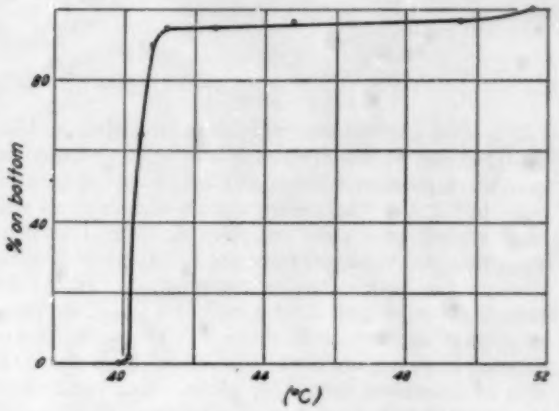

FIG. 5.—Glass No. 632, 2400 r.p.m., 150- to 200-mesh.

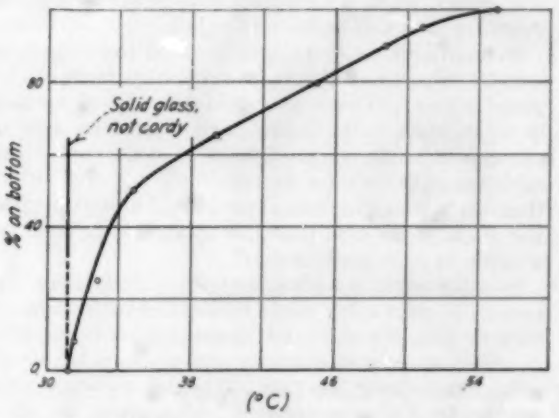

FIG. 6.—Glass No. 91, 2400 r.p.m., 150- to 200-mesh.

TABLE II

ANALYSIS OF SEPARATED FRACTIONS OF GLASSES NO. 632 AND NO. 91

	Glass No. 632: 6% cuts, purified, 10 gm. of 200- to 325-mesh, 2400 r.p.m.		Glass No. 91: 20% cuts, not purified, 1.5 gm. of 150- to 200-mesh, 1200 r.p.m.	
	Change in light fraction*	Heavy fraction	Change in light fraction*	Heavy fraction
SiO_2	+(2.07)†		(+2.64)†	
SiO_2	+ 2.15 ‡	72.44	+2.30 ‡	71.20
Na_2O	− 0.80	16.28	− 0.80	15.83
Al_2O_3	+ 0.11	1.31	− 0.02	0.96
CaO	− 0.85	4.77	− 0.78	5.73
MgO	− 0.61	3.30	− 0.70	3.71
BaO		0.46		
		98.56		97.43

* Light fraction minus heavy fraction.
† Direct determination of silica.
‡ Silica by difference.

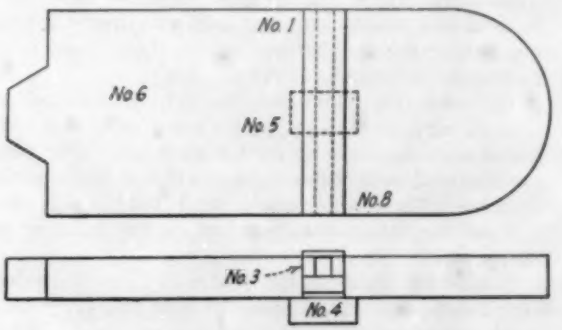

FIG. 7.

TABLE III

ANALYSIS OF SAMPLES OF FLINT GLASS NO. 632

Column (1) typical analysis; (2) melting end, front of throat; (3) bottom of throat; (4) stagnant near patch; (5) corner refining end; (6) between center line and wall; (7) between throat and dog house.

	Glass from frozen tank drained to low level					Stagnant glass, melting end	
	(1)	(2) No. 5	(3) No. 4	(4) No. 3	(5) No. 8	(6) No. 1	(7) No. 6
SiO_2	73.09	−1.21	−1.26	−0.18	−0.12	−13.25	−15.40
Na_2O	16.10	+0.25	−0.02	−0.51	−0.57	− 1.28	− 4.44
Al_2O_3	1.46	+0.57	+0.60	+0.93	+1.70	+20.94	+27.65
CaO	4.56	+0.31	+0.21	−0.05	−0.48	− 3.63	− 4.30
MgO	3.27	−0.15	+0.14	−0.10	−0.42	− 2.62	− 3.27
	98.48						

When production was stopped on the tank making glass No. 632, it was drained to a level of 4 inches and samples of glass were removed from the positions indicated in Fig. 7. The analyses of these samples as well as of typical good glass are given in Table III. The glass that was removed from the main stream flowing through the tank varies in composition; except for samples Nos. 4 and 5, the main variation in these samples is an increase in alumina. The variations in general, however, are hard to account for by the addition of aluminous refractory alone. Combination of the noncordy production with this stagnant glass evidently cannot account for the kind of composition changes observed in the cordy production because the change in silica in the stagnant glass is in the opposite direction from that in the cordy glass.

Neither cord seems to have resulted from direct or indirect solution of aluminous refractory, from incomplete melting, or from segregation of batch. A mistake in batch, such as the substitution of sand for soda in one unit of batch, is a possible cause of the cord. The cords may persist for some time, however, and both of these cords were eliminated only by rebuilding the tank; the origin of the cord therefore appears to be a source which acts quite continuously.

Stoichiometric considerations show that about 150 pounds of silica a day would be required to produce the cord in glass No. 632; but because these cords were observed to vary in intensity and the sample showed maximum severity, less than 150 pounds a day are actually used. This amount could originate in the silica refractory of the crown, which, when attacked by alkali dusts, is known to cause strings and drops of silica in the glass. The foregoing conditions may be a form of this attack, aggravated by conditions in temperature or firing which accompany the extreme thinness of the flux blocks at the flux line.

The curve (Fig. 8) for glass No. 472, which contains a C grade cord, shows a tail on the low density end, indicating contamination by foreign materials. The composition change in Table IV shows this to be primarily alumina. There is no history of the cord in this case, nor are there any detailed data on the tank or on its operation.

The cord in glass No. 601 (Table IV), showing a density-distribution curve similar to glass No. 472, was B grade and appeared as a fine streak in the ware. It was localized in one shop. Excessive corrosion was found on one floor block in the refining end near that shop

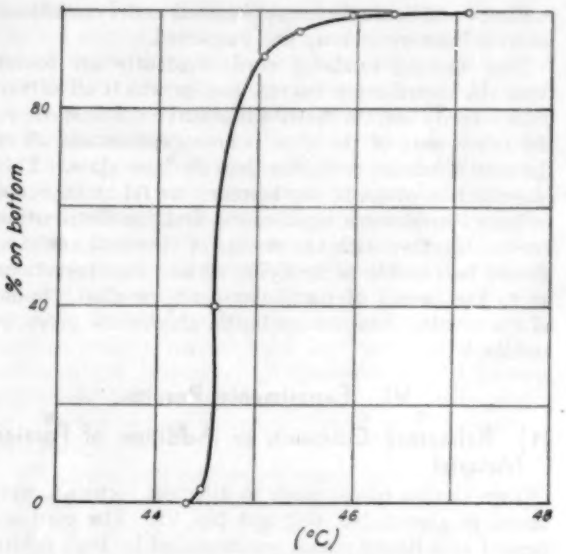

FIG. 8.—Glass No. 472, 2400 r.p.m., 150- to 200-mesh.

TABLE IV

ANALYSIS OF SEPARATED FRACTIONS FOR GLASSES NO. 472 AND NO. 601

	Glass No. 472: 6% cuts, not purified, 9 gm. of 200- to 325-mesh, 2400 r.p.m.	
	Change in light fraction	Heavy fraction
SiO_2	+0.06	69.53
Na_2O	−0.19	12.78
K_2O	−0.02	1.63
Al_2O_3	+0.40	3.01
CaO	−0.25	11.65
BaO		0.50
		99.10

	Glass No. 601: 1.8% cut, purified, 20 gm. of 200- to 325-mesh, 2400 r.p.m.	
	Change in light fraction	Heavy fraction
SiO_2	−0.30	
Na_2O	−0.16	15.84
Al_2O_3	+0.43	1.50
CaO	+0.03	4.79
MgO	+0.00	3.29
BaO		0.96

after the tank was cooled. These facts plus the tailed distribution curve and the high alumina content of the cord show that the cord was caused specifically by tank block corrosion.

(2) Batch Weighing, Handling, and Incomplete Melting

A number of cords have been analyzed for which the distribution curves showed no group of the powder to be homogeneous; the integrated S-shaped curve indicates that departures in density from the average are about as probable for increases as for decreases. Such curves would be expected when inaccurate scales give variations in composition or when there is serious batch segregation or incomplete mixing or melting.

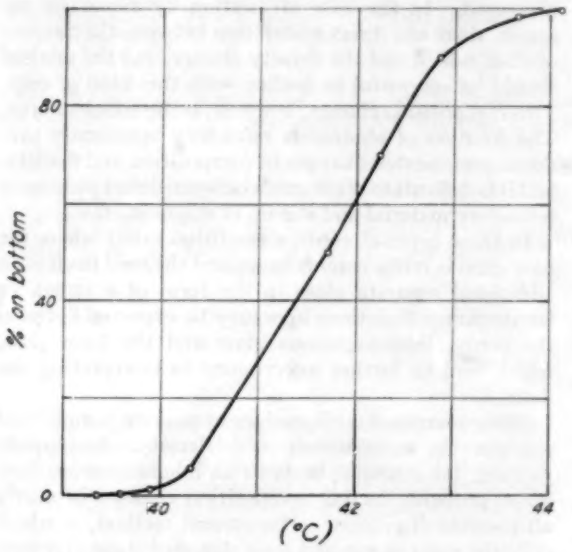

FIG. 9.—Glass No. 851, 2400 r.p.m., 150- to 200-mesh.

Figure 9 was obtained on glass No. 851, which had a cord of B to C grade. The distribution curve indicates that heavy and light as well as average density glass exists. The composition changes, primarily in soda and silica, are given in Table V. Batch segregation was suspected to be the cause of the cord.

The cords from glasses Nos. 31 and 1012, with S-shaped distribution curves, had the composition changes shown in Table VI. These were generally distributed C-grade cords of moderate polariscopic strain. Inaccuracies in batch weighing were known to exist.

TABLE V

ANALYSIS OF SEPARATED FRACTIONS FOR GLASS NO. 851

	5% cuts, purified, 10 gm. of 200- to 325-mesh, 2400 r.p.m.	
	Change in light fraction	Heavy fraction
SiO_2	+0.78	
Na_2O	−0.58	14.44
Al_2O_3	0.00	2.20
CaO	−0.26	8.50
MgO	+0.06	1.25

The composition changes and S-shaped curves indicate batch-weighing errors as a likely cause. Incomplete or differential melting, however, is not eliminated as a cause. In glass No. 491, with an S-shaped distribution curve, complicated composition changes are shown (Table VII). The changes in CaO and MgO suggest a change from calcite to dolomite lime, although segregation of cullet is also a possibility. Indications of the same kind of change in the dolomitic ratio have been found in other glasses.

TABLE VI

ANALYSIS OF SEPARATED FRACTIONS OF GLASSES NO. 1012 AND NO. 31

	Glass No. 1012: 1.4% cuts, purified, 40 gm. of 200- to 325-mesh, 2400 r.p.m.		Glass No. 31: 5% cuts, not purified, 10 gm. of 150- to 200-mesh, 2400 r.p.m.	
	Change in light fraction	Heavy fraction	Change in light fraction	Heavy fraction
SiO_2	(+0.28)		(+0.40)	
SiO_2	(+0.56)	71.54	+0.41	72.36
Na_2O	−0.06	18.09	−0.28	16.90
Al_2O_3	−0.02	0.84	+0.05	1.02
CaO	−0.28	5.06	−0.14	5.22
MgO	−0.20	3.33	−0.04	3.17
		98.86		98.76

TABLE VII

ANALYSIS OF SEPARATED FRACTIONS OF GLASS NO. 491

	5% cuts, purified, 10 gm. of 150- to 200-mesh, 2400 r.p.m.	
	Change in light fraction	Heavy fraction
SiO_2	+2.01	71.63
Na_2O	−1.60	17.59
Al_2O_3	+0.15	0.81
CaO	−1.90	7.21
MgO	+1.34	1.56
		98.80

VII. Experimental Limits of the Method

(1) Measurement of Small Density Differences

Runs are made at speeds of 2400 and 3600 r.p.m., with corresponding radial accelerations of 630 and 1430 times gravity. The pressures developed at the bottom of the tube (35 mm. height of liquid, 2.5 gm. per ml. of density) are 5.3 and 12 atmospheres at these speeds. These pressures cause an approximately constant density gradient (for mixtures of tetrabromomethane and isopropylsalicylate, or 1, 2, 4-trichlorobenzene of density near 2.5 gm. per ml.) whose values are 2.3×10^{-5} gm. per ml. per mm., measured along the tube at 2400 r.p.m., and 5.2×10^{-5} gm. per ml. per mm. at 3600 r.p.m.

If the centrifuge head is balanced, no trouble is experienced from vibrations which might stir up the suspending liquid and prevent particles from taking their equilibrium position in the liquid. Relative density can be measured under these conditions in the small temperature interval over which the particles neither sink nor float. In this temperature interval, the den-

sity of the liquid, which varies from top to bottom of the tube, at some point equals that of a particle, and the particle moves to this position in the tube.

The density of large or small pieces of glass or of other materials may thus be compared accurately with this centrifuge. Their positions in the centrifuge can be estimated to within 1 mm. so that relative densities can be found for the slower speed and acceleration to within the figures given previously, namely, 2.3×10^{-5} gm. per ml. This figure is somewhat larger than the sensitivity of a similar method of comparing densities in which the rate of motion of the suspended particle in the gravitational field is observed with a telescope; Hutchison and Johnston[4] measured relative densities by this method to 5×10^{-6} gm. per ml., an improvement of five times over the above sensitivity. The latter method is simpler for large particles, and the centrifuge offers no particular advantages until the particle size becomes small.

(2) Apparent Inhomogeneities Caused by Adsorption by Powder

Optical glass powders, 150- to 200-mesh in size, have an apparent inhomogeneity of about 0.00015 gm. per ml. At 2400 r.p.m., for example, the powder eventually will occupy a region of the liquid having a radial spread of 6 mm. at a temperature such that the powder is not crowded to one end of the liquid. The boundary for the most dense particles in this region is usually quite sharp; the other boundary is somewhat diffuse. A large fragment of the same glass will have an apparent density 5×10^{-5} gm. per ml. greater than even the most dense particles in the powder. With water solutions of thallous malonate as the suspending liquid, the density change is an increase so that large fragments apparently are the least dense. This apparent inhomogeneity increases as the particle size decreases. Most of the 200- to 325-mesh particles are spread over an interval of 0.0006 to 0.0008 gm. per ml., and the remainder, consisting of very fine particles not removed by sieving and washing, occupy an even greater density interval. This figure for 200- to 325-mesh particles is somewhat greater than that given before,[1] but it is more reliable because of improved apparatus. Because these results are independent of whether or not the suspension is sealed off under vacuum, open tubes sealed with rubber stoppers are now being used. The heat treatment of the powders and liquid is the same as before.

The apparent inhomogeneity observed is probably due to the incomplete removal of substances adsorbed by the glass surface. A monomolecular film of water, density 1, would change the density of a 0.002-in. sphere by nearly 0.0001 gm. per ml., and there is no reason to suppose that monomolecular films have been removed by the procedure given by the present writers. It is doubtful whether these films can be removed from the powder surface, and particle sizes smaller than 325-mesh thus do not appear to be practical in this method of analysis.

VIII. Conclusions

An objection to the present method of cord analysis is that the glass to be separated may not be representative of the cord. The cord itself is inhomogeneous, and there is a tendency to select the part of the cord which varies most in density. The other parts of the cord are not separated and cannot be considered by the present methods.

Whether or not the process can be used to work back from the observed composition and density differences to the source of the cord depends on how characteristic of the source are the composition changes which are measured. In the case of dilution by silica, for example, there is a direct correlation between the amount of silica added and the density change, and the method should be successful in dealing with this kind of cord. This composition change, however, is the simplest type. The solution of aluminous refractory apparently produces complicated changes in composition and density, and it is difficult to distinguish between direct pick-up of refractory material and stir-up of stagnant glass.

In these types of cords, a condition exists where the base glass is fairly homogeneous and the cord itself is an additional separate glass in the form of a streak or lamination. Reactions here may be expected between the cordy, inhomogeneous glass and the base glass, which lead to further uncertainty in interpreting the data.

Other sources of cord produce even more complicated changes in composition and density. Incomplete melting, for example, leads to an inhomogeneous base glass, probably having composition changes in nearly all possible directions. The present method, in which only the most dense and least dense of these compositions are selected, is seriously limited for a complete investigation of incomplete melting.

Although an absolutely complete diagnosis of cords cannot be given, the information obtained by the use of density differences has some value in classifying cords, as follows: (1) In case all of the cord is lighter or heavier than the base glass, the addition of foreign material to the glass or some sudden and constant change in the batch is indicated, for example, cords caused by a single gross mistake in the batch house, by refractory pick-up, or by stir-up. (2) If an S-shaped distribution curve is found, there are either several contributing causes of the cord or some single cause for the kind of curve that exists, such as incomplete melting, poor mixing, or segregation of batch or constantly occurring mistakes in weighing the batch.

Chemical analysis of the separated fractions may also determine materials with which the glass is diluted, or it may be used generally to distinguish further among the various types of cords that have been described.

PRESTON LABORATORIES
BUTLER, PENNSYLVANIA

[4] C. A. Hutchison and H. L. Johnston, "Determination of Crystal Densities by the Temperature of Flotation Method; Density and Lattice Constant of Lithium Fluoride," *Jour. Amer. Chem. Soc.*, **62** [11] 3165–68 (1940); *Ceram. Abs.*, **20** [2] 56 (1941).

CERAMIC ABSTRACTS

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AMERICAN CERAMIC SOCIETY

Ross C. Purdy, Editor

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Journal Reference: The journal name appears in italics, followed by the volume (bold-faced), issue number (in brackets), page numbers, and year (in parentheses).

August, 1941
20—8

Abrasives

Safety-tread floors help prevent accidents. New manufacturing methods. Fr. *Beiserei* (in *Emailwaren-Ind.*, **18** [11–12]), **6** [3] 5–6 (1941).—Floors for halls, hospitals, factories, etc., which wear well and are not slippery when wet, are made by scattering silicon carbide uniformly with a sifter on freshly laid cement. A grain size of 12 to 30 is suitable, and 1 kgm. silicon carbide per sq. m. suffices for normal wear, more being used for harder mechanical wear. Floor slabs are also being surfaced with silicon carbide. M.V.C.

SEPARATE PUBLICATION

Abrasive Materials. Robert W. Metcalf. Reprint from U. S. Bur. Mines Minerals Yearbook, 1940. 16 pp. Price 5¢. R.A.H.

PATENTS

Abrasive article. S. S. Kistler and C. E. Barnes (Norton Co.). Can. 396,663, May 20, 1941 (Jan. 26, 1939; in U. S. Jan. 28, 1938). G.M.H.

Abrasive disk. R. D. Kehoe, R. B. Easty, and W. H. Sayre. U. S. 2,246,362, June 17, 1941 (Feb. 8, 1940).

Abrasive paper or cloth. Tosimasa Takebe (Rikagaku Kenkyuzyo). Japan. 133,123, Nov. 9, 1939; *Chem. Abs.*, **35**, 3408 (1941).—Paper or cloth is moistened with formalin, tannin, or alum solution by spraying, the same side or the other side is coated with aqueous glue or glue with 1 or more of $C_3H_5(OH)_3$, AcOH, PhOH, salt of Hg, Cu, or Pb, over which sand moistened with water or with a solution containing formalin, alum, or tannin is applied, and the product is softened by heating with steam or hot air, dried, and coated with a dilute solution of drying oil.

Abrasive tools. British Thomson-Houston Co., Ltd. Brit. 536,518, May 28, 1941 (May 31, 1939).

Abrasive wheel. Norton Grinding Wheel Co., Ltd. Brit. 536,508, May 28, 1941 (March 29, 1939).

Apparatus for dressing bonded grinding wheels. Charles Tindall (Pittsburgh Plate Glass Co.). U. S. 2,244,478, June 3, 1941 (Sept. 28, 1937).

Brake-shoe grinder. E. C. Broxon. U. S. 2,246,290, June 17, 1941 (March 6, 1939).

Cam grinder. H. E. Balsiger and R. E. Price (Landis Tool Co.). U. S. 2,243,410, May 27, 1941 (July 22, 1938).

Dense nonmetallic article. J. A. Boyer and C. G. Rose (Carborundum Co.). Can. 396,346, May 6, 1941 (July 3, 1937). G.M.H.

Drill-grinding machine. E. J. Hornberger. U. S. 2,245,858, June 17, 1941 (Jan. 26, 1940).

Gear lapping and finishing machine. J. C. Drader and J. D. Rovick (Michigan Tool Co.). U. S. 2,245,654, June 17, 1941 (Aug. 24, 1935).

Grinder. J. E. Venable (H. Y. Kitchell). U. S. 2,244,586, June 3, 1941 (March 27, 1940).

Grinding or abrading machines. Parnall Aircraft, Ltd., and J. H. Colbert. Brit. 536,413, May 28, 1941 (Oct. 11, 1939).

Grinding disk. I. R. Shub (Gardner Machine Co.). U. S. 2,246,223, June 17, 1941 (Jan. 7, 1939).

Grinding machine. B. C. Spurling (Bentley Engineering Co., Ltd.). U. S. 2,246,023, June 17, 1941 (Sept. 11, 1940).

Grinding machine, swivel table adjustment. C. G. Flygare (Norton Co.). U. S. 2,244,643, June 3, 1941 (Oct. 8, 1938).

Grinding wheels and means for attaching them to working shafts. J. R. Brown. Brit. 536,120, May 14, 1941 (Feb. 8, 1940).

Honing apparatus. W. D. Schmidt (Heald Machine Co.). U. S. 2,244,806, June 10, 1941 (March 11, 1936).

Honing or lapping machines. A. F. Burgess (Barnes Drill Co.). Brit. 535,816, May 7, 1941 (Sept. 19, 1939).

Horizontal honing machine. H. J. Caldwell (Barnes Drill Co.). U. S. 2,246,199, June 17, 1941 (July 21, 1939). A. M. Johnson (Barnes Drill Co.). U. S. 2,245,922, June 17, 1941 (June 16, 1939).

Internal grinding machine. H. L. Blood (Heald Machine Co.). U. S. 2,243,371, May 27, 1941 (April 5, 1939).

Machine for lapping toothed elements. J. M. CHRISTMAN (Packard Motor Car Co.). U. S. 2,245,462, June 10, 1941 (April 22, 1935; renewed May 9, 1938).

Manufacture of abrasive articles. E. C. SCHACHT (Behr-Manning Corp.). U. S. 2,245,301, June 10, 1941 (Nov. 20, 1931).

Manufacture of accurately dimensioned and/or surface-finished hollow cylindrical metal elements. MICROMATIC HONE CORP. Brit. 535,985, May 14, 1941 (Feb. 23, 1939).

Means for trimming shaped grinding wheels. A. C. WICKMAN. Brit. 536,330, May 21, 1941 (Oct. 9, 1939).

Method and apparatus for abrading. MICROMATIC HONE CORP. Brit. 536,261, May 21, 1941 (Nov. 18, 1938).

Portable grinding device. CALVIN ERDMAN. U. S. 2,245,968, June 17, 1941 (Aug. 1, 1939).

Portable grinding device, especially for grinding crankshafts. L. K. TILANDER. U. S. 2,243,925, June 3, 1941 (Feb. 1, 1939).

Precision spindle for grinding wheels. R. M. SEVERANCE. U. S. 2,244,734, June 10, 1941 (March 15, 1939).

Profile truing device for grinding wheels. LIDKÖPINGS MEKANISKA VERKSTADS AKTIEBOLAG. Brit. 536,300, May 21, 1941 (Jan. 2, 1939).

Resin-bonded abrasive article. S. S. KISTLER (Norton Co.). Can. 396,667, May 20, 1941 (March 3, 1939; in U. S. March 8, 1938). S. S. KISTLER AND C. E. BARNES (Norton Co.). Can. 396,664 to 396,666, May 20, 1941 (Jan. 26, 1939; in U. S. Jan. 28, 1938). G.M.H.

Roll-grinding machine. C. G. FLYGARE (Norton Co.). U. S. 2,243,336, May 27, 1941 (July 12, 1940).

Shaping or truing of grinding wheels for precision gear grinding. G. S. THURLEY AND BRITISH GEAR GRINDING & MFG. CO., LTD. Brit. 536,299, May 21, 1941 (Nov. 8, 1939).

Supporting means for grinding wheels. C. G. EKHOLM (Lidköpings Mekaniska Verkstads Aktiebolag). U. S. 2,244,057, June 3, 1941 (Aug. 4, 1939).

Tailstocks for precision grinding machines or lathes. J. LUND, LTD., AND J. D. SCAIFE. Brit. 535,962, May 7, 1941 (Feb. 9, 1940).

Art and Archeology

Bowl. B. MAUDER. *Glashütte*, **71** [9] 131–33 (1941).—The bowl is one of the most important forms of ordinary glassware. It has a variety of shapes derived from the basic forms of the sphere, the cone, and the cylinder. The steep-walled types are the most serviceable, and they are adapted to all purposes. Being a wide-open object, all parts of the bowl are visible to the observer and must be without flaws. Most bowls are of pressed glass made by machine, but some are blown by mouth. Soda glass is used for manufacturing ordinary types of bowls; better quality bowls are made of crystal glass and potash-lime glass; lead crystal glass is required for deeply cut forms. Decoration is not necessary on bowls if the form, workmanship, and quality are superior, except in the case of art objects. Bowls of all sizes fulfill many uses which have been widely extended by the discovery of heat-proof glass. Related groups of bowl forms are sketched. M.V.C.

Chinese art and mores traced in pottery. ANON. *Art News*, **40** [6] 7 (1941).—An exhibition of Chinese pottery and porcelain at the Mills College Gallery comprises 300 examples, from prehistoric to the T'ang period, of tomb statuettes, vessels, and decorative tile. M.E.P.

Development of barbaric ornament in Britain. T. D. KENDRICK. *Jour. Brit. Archaeological Assn.*, **1**, 79–92 (1937).—Various forms of ornament on early British brooches, plaques, etc., are discussed in an effort to trace the effect of the Roman withdrawal and consequent removal of classical restraint on the style of the Britons. Romano-British champlevé and Kentish cloisonné enameling emphasized geometric patterns, particularly cruciform axes and star-shaped designs; under Saxon and Jutish influence, design and execution deteriorated, barbaric mosaics becoming typical. With the Saxon conquest (about A.D. 600), enamels disappeared abruptly. Illustrated. K.W.W.B.

First baron of glass. MARGARET O'BRIAN. *Coronet*, **10** [2] 15–17 (1941).—Henry William Stiegel came to Philadelphia from Cologne, Germany, in 1750. His first business venture was the production of stoves with the Stedman brothers. His success led him to invest in a huge tract of land north of Chickies' Creek, and there he laid out the town of Manheim in 1762. His large estate and mansion and lavish living in Lancaster County gave him great prestige and perhaps his title of "baron." His hobby of experimental glass blowing during his iron-business days grew into a full-fledged glass factory which could compete with the best European manufacturers. He lost everything in the pre-Revolutionary depression and returned to work as a foreman in his first iron mill. He died poor and forgotten, but he is famous today for the glowing shapes of his bottles and glasses, the classically simple daisy-in-a-square pattern, and the deep violets, solid blues, and soft ambers of the most precious objects in collections of American glass. M.E.P.

Garden sculpture. J. L. *Art News*, **40** [4] 34 (1941).—An exhibit at the Clay Club shows an almost rediscovered use of fired clay or terra cotta for fountain figures, weather vanes, and abstractions. "Three Graces" by Earleen Kirby is illustrated. M.E.P.

Medieval stained glass of Long Melford Church, Suffolk. C. WOODFORDE. *Jour. Brit. Archaeological Assn.*, **3**, 1–63 (1938).—Details of each window are given, together with illustrations in color and monotone. Stylistic analyses of their origins are presented, results in most of them being ascribed to Norwich. K.W.W.B.

Meissen porcelain for Poland and Russia. F. FICHTNER. *Ber. Deut. Keram. Ges.*, **21** [12] 487–520 (1940).—Twelve illustrations, mostly of porcelains in the Zwinger State Porcelain Gallery, Dresden, are included. W.H.H.

Norsey Wood "camp." DAY KIMBALL. *Jour. Brit. Archaeological Assn.*, **3**, 139–51 (1938).—Pre-Belgic, Belgic, and Romano-British ware was discovered on this site. The earliest pottery (pre-Belgic, i.e., Hallstatt or Iron Age "A") is a soft handmade ware with an admixture of coarse grit. The second group, also pre-Belgic, is a development of the first. This pottery represents a pure evolution, and, from its site, it was probably the first to be used by immigrant Belgic tribes (about 75 B.C.). Belgic ware is well represented, and specimens are described with details of their texture, material, style, and processing. The last stage of this type was a fine red ware. The Roman pottery belongs almost entirely to the first century and is not closely datable. Vessels and sherds are illustrated. K.W.W.B.

Of ships and sails and *chinoiserie*. VIRGINIA N. WHITEHILL. *Art News*, **40** [6] 10–14 (1941).—The exhibition, "The China Trade and Its Influences," at the Metropolitan Museum covers the period from the discovery of the sea routes to the Far East in the 16th century to the opening of the Suez Canal and shows the vast difference between the early collecting of real Chinese *objets d'art* and the later craze for *chinoiserie* and between the choice blue and white Ming and the Chinese export porcelain. Porcelain, the last product of Chinese culture and the first to reach the West, was occasionally a carefully chosen gift but more often merely ballast for the lighter spice and tea. In Europe, porcelain was first made in Germany after Böttger discovered the Saxon source of kaolin. While Kändler developed the hard-paste porcelain there, soft-paste porcelain was developed at St. Cloud in France where designers copied blanc de chine. In England, however, "china" became the synonym for porcelain as the custom of tea drinking became national. The curious commodity, Chinese Lowestoft, named for the city of import, was mass-produced for the Western market and comprised especially handled cups, mugs, plates, and pitchers with European portraits, armorial bearings, and Freemasonic emblems. In spite of the stepped-up Chinese import, the excellent

demand provided the kilns at Chelsea and Staffordshire an opportunity to experiment with the Chinese style. Illustrated. M.E.P.

Symbolism in Chinese porcelain decoration. CHAO MING CHEN. *Bull. Amer. Ceram. Soc.*, **20** [6] 196–207 (1941).—23 figures.

BOOKS

Early Churches in Palestine. J. W. CROWFOOT. Oxford University Press, Humphrey Milford, London. Price 8s 6d. Reviewed in *Times Lit. Supp.*, **40** [2043] 148 (1941).—The use of mosaic is of chief ceramic interest. The prevalence of mosaic in Palestinian churches may have been due to the survival in the adjoining Phoenicia of an old-established glass industry. K.W.W.B.

Indian Art of the United States. FREDERIC H. DOUGLAS AND RENÉ D'HARNONCOURT. Museum of Modern Art, New York. Price $3.50. Reviewed in *Times Lit. Supp.*, **40** [2047] 207 (1941).—The book is based upon an exhibition prepared by the Indian Arts and Crafts Board of the U. S. Department of the Interior and is primarily pictorial. The illustrations cover the fields of textiles, ceramics, painting, and carving. Descriptive notes and a full bibliography are included. K.W.W.B.

Lachish II (Tell Ed-Duweir): The Fosse Temple. OLGA TUFNELL, CHARLES H. INGE, AND LANKESTER HARDING. Oxford University Press, Humphrey Milford, London. Price 25s. Reviewed in *Times Lit. Supp.*, **40** [2039] 107 (1941).—This is the first installment of the work at Tell Ed-Duweir, in south Palestine, which is considered to be the site of the biblical city of Lachish. Buildings erected at various dates on an outlying site, inscriptions, small objects, and pottery are described. Illustrated. K.W.W.B.

Oxoniensia: Vol. V. Oxford Architectural and Historical Society, 1940. Price £1 1s. Reviewed in *Times Lit. Supp.*, **40** [2046] 195 (1941).—Among various archeological papers is "New Discoveries of Neolithic Pottery in Oxfordshire," by E. T. Leeds and others on recent excavations in the same area. K.W.W.B.

Sculptor's Way. BRENDA PUTNAM. John Lane, London. Price 35s. Reviewed in *Times Lit. Supp.*, **40** [2041] 131 (1941).—Sections dealing with plaster casting and ceramic sculpture, contributed by specialists, are included. K.W.W.B.

PATENTS

Designs for:

Bottle. OWSLEY BROWN (Brown-Forman Distillery Co.). U. S. 127,478, May 27, 1941 (March 12, 1940). B. D. FUERST (Owens-Illinois Glass Co.). U. S. 127,618, June 3, 1941 (Nov. 26, 1940). A. I. LORENZEN (Owens-Illinois Glass Co.). U. S. 127,585 and U. S. 127,586, June 3, 1941 (Dec. 14, 1940). U. S. 127,684, June 10, 1941 (Dec. 14, 1940).

Bottle. O-CEDAR OF CANADA, LTD. Can. 13,008 and 13,009, March 29, 1941. V-9 BEVERAGE CO., LTD. Can. 13,011, March 29, 1941. G.M.H.

Glass ash tray. T. C. HEISEY (A. H. Heisey & Co.). U. S. 127,620, June 3, 1941 (April 1, 1941).

Glass lotion bottle. 303 CHEMICAL CO., LTD. Can. 13,031, April 12, 1941. G.M.H.

Glass statuette. T. C. HEISEY (A. H. Heisey & Co.). U. S. 127,473, May 27, 1941 (March 18, 1941).

Pattern for glass tableware. OAKLEY, JACKSON & FAREWELL, LTD. Can. 13,038, May 3, 1941. G.M.H.

Plate. PASCAL L'ANGLAIS (Mayer China Co.). U. S. 127,486, May 27, 1941 (April 3, 1941).

Teapot. P. V. GARDNER (Corning Glass Works). U. S. 127,567, June 3, 1941 (March 5, 1941).

Water-closet bowl. A. J. LYCZAK (Kokomo Sanitary Pottery Corp.). U. S. 127,707, June 10, 1941 (Sept. 23, 1940).

Cements

Hydrated calcium ferrites and complexes that originate from tricalcium ferrite by association with various calcium salts. GIOVANNI MALQUORI AND VITTORIO CIRILLI. *Ricerca Sci.*, **11** [5] 316–21 (1940).—Tetracalcium ferrite is prepared by slowly adding to saturated limewater (20 liters) 20 cc. of a $FeCl_3$ solution containing 0.04 gm. of Fe_2O_3 per cc. The ferrite obtained is made up of lamellar hexagons; it has a chemical composition corresponding to the formula $4CaO \cdot Fe_2O_3 \cdot 12H_2O$. Its dehydration takes place slowly up to 100°C. and is completed at about 800°C. The thermal dehydration curve and X-ray analysis of $4CaO \cdot Fe_2O_3 \cdot 12H_2O$ show considerable similarity to those of $4CaO \cdot Al_2O_3 \cdot 12.3H_2O$. Tricalcium ferrite has been prepared by precipitation with NaOH from a solution containing $FeCl_3$ and $CaCl_2$ in the ratio of 1:3. The precipitate obtained is crystalline and octahedral with a refractive index of 1.72, and when dried in vacuum on $CaCl_2$ or P_2O_5 it holds $6H_2O$. The $3CaO \cdot Fe_2O_3 \cdot 6H_2O$ is practically stable up to 250°C. X-ray studies show that the spectrum changes when the material is heated to 800°C. even if the octahedral crystal is not changed. The complete removal of the water of hydration takes place at about 1000°C., and the tricalcium ferrite decomposes to $2CaO \cdot Fe_2O_3$ and CaO. V.S.DEM.

SEPARATE PUBLICATION

Thermodynamic Properties of Gypsum and Its Dehydration Products. K. K. KELLEY, J. C. SOUTHARD, AND C. T. ANDERSON. *U. S. Bur. Mines Tech. Paper*, No. 625. Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 10¢.—New experimental data and methods of preparing samples are presented. Available thermodynamic data are correlated, and, as an elementary application of these data, the analysis of heat utilization in the gypsum-plaster kettle process is given. R.A.H.

PATENT

Refractory dental mold for casting alloys. C. J. GROSSMAN. U. S. 2,243,094, May 27, 1941 (Dec. 12, 1939).—A casting mold and mold material for metallic dentures, etc., comprise zirconium oxychloride solution 8 to 15%, magnesium oxide 0.9 to 2%, and the remainder zircon and zirconia.

Enamel

Additions to the pickling bath to prevent cracks. FR. *Beizerei* (in *Emailwaren-Ind.*, **18** [11–12]), **6** [3] 5 (1941).—Additions to the pickling bath must leave no deposit on the metal, must not lengthen the pickling time appreciably, and must act only to remove the layer of oxide without affecting the metal or permitting the occlusion of hydrogen in the latter, which causes cracks. Yeast or tar prevents corrosion but soils the metal. Some vegetable poisons, e.g., strychnine, in small amounts have a high protective action. French Patent 518,628 describes the manufacture of pickling additions in which natural anthracene, sulfite liquor, residue from the production of naphthalene, waste acids from the purification of mineral oil, tar, paraffin, etc., are used. The same method is treated in German Patent 309,264. The use of raw or synthetic quinoline, naphtha quinoline, and derivatives of these compounds, distillate containing quinoline, and quinoline yellow is described in French Patent 536,964.

Another German patent uses a reaction product of an arylthiourea and an aldehyde, e.g., thiocarbanilide and formaldehyde. M.V.C.

American Stove's new research laboratory. L. G. FRIERSON. *Better Enameling*, **10** [1] 12–13 (1939).—The American Stove Company's new research laboratory is described briefly. Illustrated. J.J.H.

Control of domestic enameling clays. FRANK J. ZVANUT. *Enamelist*, **18** [5] 13–21 (1941); see *Ceram. Abs.*, **20** [4] 84 (1941). L.E.T.

Defects in weld metal and hydrogen in steel. C. A. ZAPFFE AND C. E. SIMS. *Welding Jour.* [N. Y.], **19** [10] 377–95 (1940).—A discussion of the solubility of hydrogen in steel and the pressures generated by it indicates that the literature supports the view that H_2 may cause cracking in welds as it does flakes and fissuring in forged and rolled steels. The reaction of H_2 with C in steel to form high CH_4 pressures is postulated as the origin of internal stress causing cracking. The source of H_2 in welding may be the gases generated in the combustion of cellulosic portions of electrode coating and the arc decomposition of atmospheric moisture. Diffusion of atomic H_2 and collection at discontinuities and rifts causes high pressures of molecular H_2. The stress is relieved through the enlargement of the local storage space for H_2 which, on tensile fracture of the weld, is revealed as a bright region surrounding a cavity (termed "fisheyes" by the welding profession). The bright, silvery fracture surface was duplicated by the authors by loading steel samples with H_2 cathodically and rupturing the specimens. The blistering of enameled sheet iron is also attributed to the formation of H_2 gas at the surface of the sheet from H_2 diffusing through the sheet atomically from some internal cavity in which molecular H_2 was occluded. Peening of welds is regarded as beneficial in the removal of molecular H_2 present in rifts and blowholes in welds, and the optimum temperatures for peening are considered to be between 100° and 400°C. (212° and 752°F.). Data are presented on the effects of drying the electrode coating, ordinary storage, and welding with the electrode surrounded by wet steam. The dried rod produced weld metal of the highest strength and ductility, while the last two conditions gave approximately equal results. Other tests of welds made in dry weather and in rainy weather indicate that when the specimens were not permitted to age, the welds made in wet weather had somewhat lower strength and ductility; when the specimens were aged for two weeks at room temperature, the reverse was found. The results indicate that effusion of H_2 from the weld metal may take place slowly over a period of time at room temperature, thus increasing the ductility and strength. Tests were also made on the effect of annealing temperature and time on the removal of H_2 at temperatures of 225° to 1470°F. and periods of $^1/_4$ to 50 hr., depending upon the annealing temperature. Temperatures of 225° to about 1100°F. appear to remove H_2 as shown by values obtained for the strength and ductility of weld metal (the data are based on one specimen per test, and most of the results are within the range of experimental error in a tensile test and certainly within the usual range of scatter for duplicate welds). The optimum annealing temperature of 600°C. (1112°F.) for 15 min. is recommended with slow cooling to remove the H_2 dissolved in the steel at the annealing temperature. See *Jour. Amer. Ceram. Soc.*, **23** [7] 187–219 (1940). W.H.B.

Exhaust systems for pickling tanks. H. R. PHELPS. *Better Enameling*, **11** [3] 13–15 (1940).—P. describes and discusses exhaust systems used for ventilating and exhausting fumes from pickling tanks and rooms. Illustrated. J.J.H.

Factors influencing dry-beading defects. R. J. WHITESELL. *Jour. Amer. Ceram. Soc.*, **24** [7] 241–43 (1941).

Gauge for measuring the thickness of sheet steel. B. M. SMITH AND W. E. ABBOT. *Gen. Elec. Rev.*, **44** [2] 125–27 (1941).—A magnetic thickness gauge for rapid and accurate determination of the thickness of ferromagnetic sheet or strips is described. The equipment is fitted with two scales on its meter, one for use on low-carbon steel between 0.020 and 0.045 in. thick and one for magnetic sheets of medium silicon content ranging in thickness from 0.010 to 0.025 in. Readings are accurate to 0.001 in. L.E.T.

Latest developments in the enamel industry. H. J. KARMAUS. *Korrosion & Metallschutz*, **14**, 285–95 (1938); see "Mechanical . . .," *Ceram. Abs.*, **17** [8] 271 (1938); "Review . . .," *ibid.*, **18** [4] 94 (1939); "Latest . . .," *ibid.* [9] 234. W.N.

Manufacture of color oxides for porcelain enamels. CAMPBELL ROBERTSON. *Better Enameling*, **11** [3] 4–7, 27 (1940).—R. describes the manufacture of color oxides, discussing (1) raw materials, (2) formulation of color oxides, (3) manufacturing processes, (4) control testing, and (5) the blending of oxides. Illustrated. J.J.H.

Patents on enameling processes taken out in former Austria. P. EYER. *Emailwaren-Ind.*, **18** [5–6] 9–11 (1941).—The Austrian patent office has been merged with the German office, and, although there are now no Austrian patents, former patents held many valuable ideas for enameling processes, apparatus, etc. The compositions of several enamels without borax are tabulated; the enamels contain feldspar, sodium fluoride, aluminum fluoride, fluorspar, calcite, sodium fluosilicate, kaolin, cryolite, magnesia, potash, quartz, sand, saltpeter, soda, alumina, the best known opacifiers, metal oxides, and coloring materials. Either milk glass or materials containing lead or arsenic or boron compounds are also used. An important ingredient of the new enamel without borax is an easily fusible soda-lime-alumina silicate with additions of fluorides. The theoretical composition of the fired enamel (disregarding the loss of fluoride) should lie within the following percentages if usable enamels are to be produced: Na_2O 10 to 20, K_2O 1.5 to 5, CaO 1.5 to 6, MgO 0 to 1, Al_2O_3 5 to 10, SiO_2 50 to 65, F 1.5 to 10, Sb_2O_3 0 to 7, and SnO_2 0 to 9%. The usual white coloring materials and coloring metal oxides are used. The materials are weighed, mixed, and smelted together, drawn off in water, and ground wet with the mill additions. Ammonia containing carbonic acid is necessary for application of the enamel. The firing temperature is between 800° and 1050°, usually 900°. The finished enamel has a good gloss, withstands temperature, and has good elasticity, high tenacity, and good resistance to liquids and fruit acids. Other patents deal with the use of artificially prepared pure titanic acid as opacifier; if calcined, it is insoluble in the glaze and is said to be an excellent opacifier when mixed or ground with the previously smelted glaze or enamel, as in the case of tin oxide; 10% titanic acid added to the glaze or enamel gives a uniform white enamel. *Ibid.*, [7–8] 15–16.—Supplementary literature on the subject questions the efficacy of titanic acid as opacifier. A mixture of titanic acid and zirconium oxide or materials containing zirconium oxide or tin oxide is said to opacify well. M.V.C.

Practical thickness of partial coatings of acid-resistant enamel. GEORGE H. SPENCER-STRONG. *Jour. Amer. Ceram. Soc.*, **24** [7] 235–40 (1941).—4 figures, 1 reference.

Production of one-coat whiteware. J. J. BOEHLER. *Better Enameling*, **11** [10] 10–12, 26 (1940).—B. outlines the procedure to be followed in the production of one-coat ware. Subjects discussed in detail are (1) design and fabrication, (2) pickling, (3) mill room, and (4) ground coat. J.J.H.

Testing black oxides for strength. B. J. SWEO. *Enamelist*, **18** [5] 8–12 (1941).—Black oxides are used extensively in ground-coat frit and black-edge frit in making black-edge enamel. Four black oxides were tested in amounts of $^1/_4$, $^1/_2$, 1, and 2% in opaque and ground-coat frits. Cobalt-bearing black oxides produce a greater graying effect in opaque frit than oxides which do not contain cobalt. Cobalt-free black oxides and cobalt-bearing oxides give equivalent results when used in ground-coat frit to make black finishes. There is no relation between the graying effect or strength of a black oxide in an opaque frit and its strength in a ground-coat frit. L.E.T.

PATENTS

Ferrous metal enamel. J. L. GALLUP (Radio Corp. of America). U. S. 2,244,360, June 3, 1941 (June 9, 1939).—

A vitreous heat-resistant enamel capable of forming a coating firmly adherent to nickel consists of 55 to 65 silica, 4 to 15 calcium oxide, 5 to 10 boric anhydride, and 20 to 25% alkali composed of sodium oxide and potassium oxide and has a coefficient of thermal expansion substantially the same as that of nickel from room temperature to about 600°C., a softening point of approximately 600°C., a melting range of about 900° to 950°C., and an electrical resistivity of about 1×10^{13} ohm-cm.

Vitreous enameling. YOGORO KATO ET AL. Japan. 132,464, Oct. 5, 1939; *Chem. Abs.*, **35**, 3408 (1941).—A metal or alloy to be enameled is first spray-coated with a metal film.

Glass

A.S.T.M. Committee offers definition of glass. ANON. *Glass Ind.*, **22** [5] 216 (1941).—Subcommittee 1 of Committee C-14 has agreed upon a definition for glass which will be offered to the full committee. See "Definition . . . ," *Ceram. Abs.*, **20** [6] 140 (1941). A.P.

Calculation of density. ANON. *Glass Ind.*, **22** [5] 228–29 (1941).—Huggins' formula for computing the density of a glass from its composition ("Density . . . ," *Ceram. Abs.*, **20** [2] 41 (1941); "Symposium . . . ," *ibid.*, p. 42) is rearranged into a more familiar form: $1/\rho = \frac{f_1}{z_1} + \frac{f_2}{z_2} + \frac{f_3}{z_3} +$, where f is the fractional amount of the oxide, ρ is the density (gm. per cc.), and z is the density factor. The density factors z_M have the value $W_M/[(k + b_m)n_M + c_M m_M]$. W_M is the molecular weight of the component oxide M_mO_n; k is a constant depending on the heat-treatment of the glass (if the glass is stabilized to give maximum density, $k = 0$); n_M and m_M are the subscripts in the molecular formula; b_m and c_M are constants. Three of the four sets of factors for z_M are tabulated. Each applies to a limited range of composition. A.P.

Cause of the blue deposits occurring in glass blowing. A. DEMSKI. *Gas- & Wasserfach*, **83** [22] 253–55 (1940).—Exhaustive and systematic tests were made to determine the cause of the blue deposits occurring on glass during the blowing operation. D. concludes that they must be ascribed to S in the gas and that the thickness of the deposit depends on the amount of S burned during the blowing operation. A desulfurized gas with only 3.3 gm. S per 100 m.³ gas (20 to 25 gm. are normally present) gave, even after 9 min., a very weak deposit, and none at all was found with propane gas containing 1.5 gm. S per 100 m.³ gas. To a certain extent, the glass composition also contributes to the occurrence of the blue deposit. It is certain that CO_2, N, and water vapor are not the cause. Weak deposits, such as are often observed with unpurified gas, can usually be removed successfully by repeated heating after the glass has been washed in water. M.H.

Change in the index of refraction of glass when rapidly cooled to below the annealing range. V. A. FLORINSKAYA. *Zhur. Tekh. Fiz.*, **10**, 1582–92 (1940).—Specimens of glass were kept for definite periods at certain temperatures and then cooled rapidly to room temperature. A decrease in the index of refraction was observed for some optical glasses. No double refraction was observed. For the glass BK-10, the change occurred between 240° and 546° and amounted to as much as 3×10^{-4}. The decrease in the index became larger as the temperature of heating and the rate of cooling increased. The original index was restored by gradually cooling after reheating. The data obtained are insufficient for conclusions. B.Z.K.

Chemical and thermal behavior of glass. L. SPRINGER. *Korrosion & Metallschutz*, **14**, 381–85 (1938). W.N.

Comparison of two recent studies on refraction and dispersion of glasses. J. C. YOUNG AND A. N. FINN. *Jour. Optical Soc. Amer.*, **31**, 383–84 (1941).—The formula of Young and Finn for computing specific refraction as an additive function of weight-percentage composition ("Effect . . . ," *Ceram. Abs.*, **20** [4] 88 (1941)) is compared with Huggins' formula for refraction per gram atom of oxygen ("Refractive . . . ," and "Symposium . . . ," *ibid.*, [2] 42). The latter can be converted to a form identical with the former by a multiplying factor. The empirical constants for each formula are then directly comparable. Similar considerations apply to factors for specific dispersion. Agreement between the sets of empirical constants is good except for B_2O_3 and Al_2O_3 values. A.P.

Cracking of glass as a function of time. H. SCHARDIN, D. ELLE, AND W. STRUTH. *Z. Tech. Physik*, **21** [12] 393–400 (1940).—Glass samples were cracked by firing bullets against them. High-speed photographs were taken of the samples which were placed between polarizing sheets. The formation of longitudinal waves, transverse waves, and secondary cracks is illustrated. Preliminary results for organic glass indicate a smaller rate of cracking than that observed in inorganic glass and a variable rate of cracking. See "High...," *Ceram. Abs.*, **18** [1] 17 (1939). W.M.C.

Decimal classification of data for economy in glass raw materials and energy consumption. KURT H. BORCHARD. *Glashütte*, **71** [7] 81–83; [9] 133–36 (1941).—A plan for classifying materials and forms of energy (electricity, gas, and water) and tabulating data in a form for easy reference is described. An outline with main headings and subdivisions is shown. Every unit to be classified is given a representative term with a corresponding classification number composed of three parts: one number of three digits for the main heading, a second large number for the subdivision, and a page number. Terms and numbers are listed in an index. Card systems or notebooks can be used for filing data, and practical suggestions for arranging plans for materials and classification numbers are given. This reference classification of production needs, supply of materials and power, costs, etc., will aid working efficiency and economy. M.V.C.

Dielectric losses in boric glass at high frequencies. A. F. VALTER, M. A. GLADKIKH, AND K. I. MARTYUSHOV. *Zhur. Tekh. Fiz.*, **10**, 1593–1603 (1940).—An investigation was made of the effect of Na, Li, K, Ba, and Ca on the tangent of the angle of dielectric losses of boric glass. By substituting BaO for CaO and Li_2O for CaO but maintaining a constant total atomic concentration, the tangent varied monotonously during the interval 150° to 600°. A monotonous variation was also observed when Li_2O was substituted for K_2O in small atomic concentrations. For large concentrations of alkali, the tangent reached a minimum providing the total concentration of Li_2O and K_2O remained constant. The minimum was observed at all temperatures and became more distinct at higher temperatures. Upon the addition of an oxide such as Li_2O to a glass having one oxide only, such as K_2O, the dielectric losses were found to increase provided their total concentration was small. For large concentrations there might even be a decrease. This was observed at all temperatures. B.Z.K.

Effect of isomorphous substances on glass. ALEXANDER SILVERMAN. *Jour. Amer. Ceram. Soc.*, **24** [7] 243 (1941).

Electrolytical replacement of sodium by ammonium in glass. NORBERT J. KREIDL, BRUCE F. TRUMM, AND ROGER F. SCOTT. *Jour. Amer. Ceram. Soc.*, **24** [7] 225–28 (1941).—16 references.

Electroosmotic investigation of surface layers of glasses. V. S. MOLCHANOV. *Zhur. Fiz. Khim.*, **13**, 1124–30 (1939).—The ζ potentials of powders of quartz, apparatus glass of the binary system PbO–SiO_2, and lead sulfate in electrolytes (KCl, K_2SO_4, K_2CrO_4, $Pb(NO_3)_2$, HNO_3, and KOH) were measured. The fundamentals of the theory of the formation of a protective layer on the surface of silicate glasses were confirmed. The measurement of ζ potentials proved to be a sensitive method for determining the nature of products of the corrosion of glasses by aqueous

solutions. The surface of a glass containing 67% PbO and 33% SiO_2 which has been in contact with water or aqueous solutions can be regarded not as typically heteropolar but as similar to that of quartz. Because of the formation of a protective film on the surface of silicate glasses, the differences in the ζ potentials of apparatus glasses of different kinds should be inconsiderable. The leveling of the properties of surfaces is increased by the commonly used methods of cleaning glasses. P.B. & E.S.

Glass fibers and glass wool. H. W. *Wärme- & Kälte-Tech.*, **40** [1] 14–15 (1938).—W. gives a brief description of the two methods of manufacturing glass fibers and glass wool (the centrifuge method and the blowing method) and mentions a number of applications such as insulation against heat and cold, as material for light dispersion, and as filter material for oils, acids, etc. W.L.

Glass signal bells. H. JUNGNITZ. Translated in *Glass Ind.*, **22** [5] 213–14 (1941); see "Signal . . . ," *Ceram. Abs.*, **19** [9] 212 (1940); see also "Bells . . . ," *ibid.*, **20** [7] 166 (1941). A.P.

New laboratory building makes Corning's research facilities the glass world's finest. ANON. *Glass Ind.*, **22** [6] 251–53 (1941).—17 photographs. A.P.

Phosphates in ceramic ware: I, In opal glasses. WOLDEMAR A. WEYL. *Jour. Amer. Ceram. Soc.*, **24** [7] 221–25 (1941).—22 references.

Recent developments in glass insulators. J. K. GILLETT. *Trans. S. African Inst. Elec. Engrs.*, **31** [11] 314 (1940).—Experimental installations of toughened-glass insulators under severe operating conditions in South Africa have given good service. L.W.V.

Special glasses using nepheline and talc as raw materials: I. S. NAGAI AND T. YAMABE. *Jour. Japan. Ceram. Assn.*, **48** [572] 365–70 (1940).—The authors prepared special glasses containing large amounts of alumina and magnesia, using nepheline or nepheline-syenite as raw materials. The chemical compositions of the raw materials are as follows:

	Talc (Manchukuo)	Nepheline (Korea)	Nepheline-syenite (Korea)
SiO_2	59.59	42.40	45.56
Al_2O_3	0.36	33.62	28.33
Fe_2O_3	0.08	0.62	2.21
CaO	1.22	0.93	1.28
MgO	30.81	Trace	0.36
Na_2O		16.89	14.12
K_2O		5.99	7.41
Ignition loss	6.90	0.89	1.05

The chemical compositions of the prepared glasses are shown in the following table:

No.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Alkali
I	71.38	1.82	0.32	7.37	3.71	15.40
III	66.52	4.56	0.48	7.48	5.84	15.12
III′	68.09	4.07	0.49	13.49	5.71	8.15
V	63.91	6.93	0.46	7.45	7.52	13.73
V′	63.27	6.73	0.19	13.58	7.96	8.27
V′ (a)	64.09	5.91	0.41	14.23	7.95	7.41
X (a)	70.33	9.85	0.37	4.74	8.30	6.41

These glasses were crushed and sieved to grain sizes between 64 meshes per $cm.^2$ (opening 0.75 mm.) and 144 meshes per $cm.^2$ (opening 0.49 mm.) and boiled for 2 hr. in water. The loss in weight was measured, and the dissolved alkali was determined by titrating with $N/50$ H_2SO_4 solution. The results are given.

No.	Dissolved alkali (%)	Weight loss (%)
I	0.22	0.160
III	0.014	0.140
III′	0.009	0.116
V	0.013	0.138
V′	0.008	0.154
V′ (a)	0.007	0.114
X (a)	0.003	0.020

Conclusions are as follows: (1) When the soda content is small, increasing alumina, melting becomes hard, and the viscosity of the melt increases. (2) A large amount of nepheline can reduce the use of soda ash, but the use of nepheline-syenite increases the iron oxide. (3) Alumina and magnesia improve the water solubility. (4) From the result of these experiments, under ordinary pressure the following equation was obtained: $D = \log_{10}(N - 1/4A)$, where D = amount of titrated $N/50$ H_2SO_4 solution (cc.), N = alkali content (%), and A = alumina (%). This fact is explained by the assumption that alumina combines with alkali and silica to form the feldspathic compound $R_2O \cdot Al_2O_3 \cdot xSiO_2$, and the residual alkali combines with the residual silica to form $R_2O \cdot nSiO_2$. This residual alkali is easily dissolved in water. (5) The water-solubility test was also made under high pressures (5, 10, and 15 kgm. per $cm.^2$) in an autoclave. With pressures of 5 and 10 kgm., results were the same as those obtained with ordinary pressure, but above 15 kgm. the amount of dissolved alkali increased rapidly. Y.K.

Stained glass. JOEP NICOLAS. *Glass Ind.*, **22** [6] 254, 274–76 (1941).—N. reviews the historical development of the art and techniques of stained glass. A.P.

Surface phenomena in glass melts: II, Method of determining the surface tension of glasses. DZH. S. LEV. *Zhur. Fiz. Khim.*, **13**, 1161–66 (1939).—L. suggests a method of determining the surface tension of glasses based on observation of the behavior of vertically suspended glass threads with different loads in the temperature range at which the threads possess the properties of a plastic body. See *Ceram. Abs.*, **20** [1] 14 (1941). P.B. & E.S.

Use of the Kohlrausch method for determining the chemical resistivity of glass. V. S. MOLCHANOV. *Zhur. Priklad. Khim.*, **13**, 934–41 (1940).—The chemical resistance to the action of water and HCl were determined conductometrically for Jena glass, apparatus glass of the Druzhnaya Gorka works, window glass, molybdenum glass, electrode glass, and lead metasilicate glass. M. suggests that the resistivity be expressed by a conventional value indicating the "time of equal destruction" or by a "destruction degree-time" plot. The investigations on lead metasilicate glass showed that in the case of glasses containing no metals forming water-soluble hydroxides, the methods of resistivity determination based on the fixation of the amount of matter going over to water cannot be considered reliable. The data obtained by the conductometric method coincided with those obtained by other methods, thus confirming the expediency of the use of the Kohlrausch method. P.B. & E.S.

BOOK

Handbook of the Glass Industry. Compiled and edited by SAMUEL R. SCHOLES. Ogden-Watney Publishers, Inc., New York, 1941. 208 pp. Price $5.00.—This book was compiled for the factory engineer, the chemist, and the plant executive. It is not a treatise. It is a compilation of engineering data. It describes equipment only to the extent needed to illustrate the use of data. This book is more than a compilation; it is an encyclopedia of glass-factory data and a handy reference book. It covers raw materials, fuels, glass properties, ware defects, furnaces, and pyrometers. Exhaustive numerical, conversion, and capacity tables and numerous charts are given. It is a simple, logically arranged handbook and has a cross index and a comprehensive table of contents. R.C.PURDY

PATENTS

Air filter. GAMES SLAYTER (Fiberglas Canada, Ltd.). Can. 395,853, April 15, 1941 (Aug. 3, 1938; in U. S. Aug. 3, 1937). G.M.H.

Apparatus and method of fabricating articles from molten glass. F. L. O. WADSWORTH (Ball Brothers Co.). U. S. 2,244,273, June 3, 1941 (March 4, 1935).

Apparatus for producing a ground or polished continuous strip of glass. PILKINGTON BROS., LTD., F. B. WALDRON, L. H. DAVIES, AND J. H. GRIFFIN. Brit. 536,492, May 28, 1941 (Oct. 14, 1939).

Binder for glass-fiber threads. HANS STEINBOCK (Owens-Corning Fiberglas Corp.). U. S. 2,245,620, June 17, 1941 (July 12, 1939).

Bottle and closure. J. V. CHILES (Hiram Walker & Sons, Inc.). Can. 396,417, May 6, 1941 (April 1, 1940). G.M.H.

Building walls and glass block for use therein. T. W. ROLFH. Brit. 536,142, May 14, 1941 (Nov. 6, 1939).

Coffee-making device. G. W. WATSON. U. S. 2,245,238, June 10, 1941 (May 1, 1939).

Coffeepot. R. T. CAMERON. U. S. 2,245,182, June 10, 1941 (June 4, 1940).

Coloring glass fibers. J. F. HYDE (Owens-Corning Fiberglas Corp.). U. S. 2,245,783, June 17, 1941 (July 16, 1937).—A method of coloring fibers composed of glass containing a first-group metal includes treating them with an ionizable salt of a metal of a higher group to displace a portion of the first-group metal and subsequently reacting the higher group metal with an additional material containing an ion capable of forming a pigment therewith, whereby a pigment is formed and incorporated within the fibers.

Electric furnace. GAMES SLAYTER, F. W. ATKINSON, AND ED FLETCHER (Owens-Illinois Glass Co.). U. S. 2,244,267, June 3, 1941 (Jan. 10, 1938).—In a method of heating and melting glass in an electric furnace in which the mass of molten glass serves as a resistor to an electric current flowing between spaced cooperative electrodes, one of which is perforated with a multiplicity of openings therethrough, the steps comprise feeding cold glass batch consisting of electrically nonconducting materials in disintegrated form through the openings and thereby wiping the heat from the perforated electrode, maintaining a layer of the nonconducting materials between the perforated electrode and the molten glass, and applying very high voltages between the electrodes, whereby incipient sparking is induced within the layer and the incoming batch quenches the sparks as it passes through the electrodes.

Flue structure. W. A. TICKNOR (Corning Glass Works). U. S. 21,836, June 17, 1941 (June 7, 1940); reissue of original 2,103,602, Dec. 28, 1937 (Oct. 6, 1936).

Glass-annealing lehr. P. L. GEER (Amco, Inc.). U. S. 2,244,772, June 10, 1941 (Sept. 3, 1938).

Glass article heating and reshaping apparatus. J. C. HOSTETTER (Corning Glass Works). Can. 396,506, May 13, 1941 (Nov. 18, 1939; in U. S. Dec. 7, 1938). G.M.H.

Glass-article manufacture. HERBERT SMITH (Corning Glass Works). Can. 396,507, May 13, 1941 (Nov. 23, 1939; in U. S. Dec. 7, 1938). G.M.H.

Glass composition. H. P. HOOD (Corning Glass Works). Can. 396,186, April 29, 1941 (Sept. 2, 1938; in U. S. Sept. 9, 1937). G.M.H.

Glass dielectric element. MITSUO HIROSE AND HIROSHI KAMOGAWA (Canadian General Electric Co., Ltd.). Can. 396,178, April 29, 1941 (Feb. 8, 1938). G.M.H.

Glass fabric. GAMES SLAYTER AND J. H. THOMAS (Fiberglas Canada, Ltd.). Can. 395,852, April 15, 1941 (Nov. 24, 1937; in U. S. June 22, 1937). G.M.H.

Glass feeder shearing mechanism. T. F. PEARSON (Crown Cork & Seal Co., Inc.). Can. 396,509, May 13, 1941 (July 16, 1938). G.M.H.

Glass furnace. G. V. MCCAULEY (Corning Glass Works). Can. 396,503, May 13, 1941 (June 27, 1939; in U. S. Aug. 26, 1938). G.M.H.

Glass-furnace feeder. JOHN FERGUSON. Can. 395,945, April 22, 1941 (April 22, 1939). G.M.H.

Glassmelting and refining furnace. C. C. KINKER, J. E. MCBURNEY, R. W. HOPKINS, AND J. A. TASSICK (Owens-Illinois Glass Co.). U. S. 2,246,364, June 17, 1941 (July 24, 1937).

Glass product and method of making. EMANUEL SPIELHOLZ (Duro Test Corp.). U. S. 2,245,137, June 10, 1941 (Feb. 25, 1938).—A glass electric-light bulb having an irregular chemically etched and recrystallized surface, the surface having etched projections and also having etched portions intermediate to the etched projections, the respective projections having surfaces which are sufficiently inclined relative to each other to refract white light which is emanated from a source which is external to the bulb so as to produce colored fringes, the projections being shaped to transmit the light which emanates from the interior of the energized bulb without the substantial production of colored fringes.

Ground-glass joint. H. K. MARTIN (Corning Glass Works). Can. 396,500, May 13, 1941 (March 7, 1939; in U. S. May 24, 1938). G.M.H.

Heat-absorbing glass and method of producing. W. O. LYTLE (Pittsburgh Plate Glass Co.). U. S. 2,244,468, June 3, 1941 (April 26, 1938).

High-silica glass. H. P. HOOD AND M. E. NORDBERG (Corning Glass Works). Can. 396,504, May 13, 1941 (Sept. 20, 1939; in U. S. Nov. 4, 1938). M. E. NORDBERG AND H. E. RUMENAPP (Corning Glass Works). Can. 396,505, May 13, 1941 (Sept. 20, 1939; in U. S. Nov. 18, 1938). G.M.H.

Lead glaze. R. W. GOODWIN (General Electric Co.). U. S. 2,245,541, June 10, 1941 (July 15, 1938).—A lead glaze comprises about 40 to 60 lead oxide, 15 to 30 silica, 1% aluminum oxide, and a small amount not exceeding about 3% of alkali oxides, the glaze having a firing temperature and coefficient of expansion adapting it for fusion to glass electric-lamp envelopes.

Lehr and method of treating glassware therein. D. G. MERRILL (Hartford-Empire Co.). U. S. 2,244,113, June 3, 1941 (May 6, 1938).

Machine for aligning glass block sections and pressing them together. H. L. EASTUS (Owens-Illinois Glass Co.). U. S. 2,244,291, June 3, 1941 (Nov. 8, 1939).

Making glass sheet or plate. E. J. COOK. U. S. 2,243,194, May 27, 1941 (Feb. 21, 1938).

Manufacture of drawn glass. PETE MAGRINI (American Window Glass Co.). U. S. 2,246,053, June 17, 1941 (May 4, 1938).

Manufacturing glass rope. R. G. ROESCH (Eraser Co., Inc.). U. S. 2,245,824, June 17, 1941 (Aug. 3, 1940).

Means for spinning mineral wool. C. F. RAMSEYER. U. S. 2,243,122, May 27, 1941 (Aug. 13, 1938).

Method and apparatus for annealing glassware. D. G. MERRILL (Hartford-Empire Co.). U. S. 2,244,112, June 3, 1941 (March 2, 1936).

Method and apparatus for blowing glass. A. F. TREMBLAY (Kent-Owens Machine Co.). U. S. 2,243,267, May 27, 1941 (Oct. 13, 1937).

Method and apparatus for feeding batch to glassmelting furnaces. A. K. LYLE (Hartford-Empire Co.). U. S. 2,246,375, June 17, 1941 (Nov. 25, 1939).

Method and apparatus for the manufacture of hardened glass. G. P. DESPRET (American Securit Co.). U. S. 2,243,149, May 27, 1941 (Feb. 10, 1936).

Mirror. SEIKITI MIYASIRO AND TOSIO INAGAKI (Teisin Daizin). Japan. 132,799, Oct. 23, 1939; *Chem. Abs.*, **35**, 3407 (1941).—For silvering glass a small amount of lactic acid or lactate is added to the silvering solution.

Operating mechanism for glass-feeder plungers. M. M. CANNON, JR. (Hartford-Empire Co.). U. S. 2,246,461, June 17, 1941 (Aug. 25, 1938).

Paneled lehr belt. G. W. BATCHELL. U. S. 2,243,145, May 27, 1941 (Feb. 16, 1940).

Polished glass strip making apparatus. F. B. WALDRON (Pilkington Bros., Ltd.). Can. 396,042, April 22, 1941 (Dec. 26, 1939). G.M.H.

Production of colored glass fibers. ALGEMEENE KUNSTVEZEL MIJ. N. V. Brit. 536,236, May 21, 1941 (Nov. 4, 1938).

Refractory glass. J. H. PARTRIDGE (Canadian General Electric Co., Ltd.). Can. 395,938, April 22, 1941 (Feb. 4, 1937). G.M.H.

Sealing glass to metal. BRITISH THOMSON-HOUSTON CO., LTD. Brit. 536,362, May 21, 1941 (April 7, 1939).

Shearing mechanism for use with devices for feeding molten glass to forming machines. T. F. PEARSON (Crown Cork & Seal Co., Inc.). U. S. 2,245,813, June 17, 1941 (July 14, 1938).

Siliceous material. N. S. GARBISCH. U. S. 2,245,473, June 10, 1941 (April 14, 1939).—A process of making glass comprises smoothing the surfaces of glass plates by grind-

ing them with a slurry of sand of glass-batch purity under runners composed of material, debris from which is nondeleterious to a glass batch, until the sand is broken too fine for further grinding operations and comprises silica and about 20 to 40% of glass abraded from the glass plates, removing excess water from the sand, incorporating glass fluxes, and melting the mixture to form additional glass.

Stenciling apparatus. K. B. VOLLSTORF (Libbey Glass Co.). U. S. 2,244,272, June 3, 1941 (March 30, 1940).

Tempered glass and process for manufacture. BERNARD LONG (American Securit Co.). U. S. 2,244,715, June 10, 1941 (Dec. 17, 1935).—A new article of manufacture comprises a sheet of glass having at least a portion thereof tempered to produce zones of different degrees of tempering, each of the less-tempered zones being entirely surrounded by a higher-tempered zone.

Yellow-glass composition. H. H. BLAU AND W. H. GILLETT (Corning Glass Works). Can. 396,502, May 13, 1941 (May 30, 1939; in U. S. June 25, 1938). G.M.H.

Structural Clay Products

Critical valuation of different processes for determining the strength of brick. O. KALLAUNER. *Zprávy České keram. společnosti*, **16** [1–2] 18–23 (1939).—Brick is tested principally for resistance to pressure and transverse strength. The resistance to pressure is tested on whole brick, single halves, two halves (one laid on or mortared on the other), fractions of brick, or brick cubes. A comparison shows that the most correct and appropriate method for determining the resistance to pressure uses cubes of brick, although the average strength of the brick mass is not detected because of the small dimensions of the cube and the inhomogeneity of the mass. A comparison of the resistance to pressure determined on a cube with the transverse strength is an indication of the inner imperfection of the material. The determination of the transverse strength is important in judging the quality of a brick. The combined determination of the transverse strength and the resistance to pressure according to the proposal of Drögsler is recommended. K. confirms the theory that a definite relationship exists between the resistance to pressure and the transverse strength of brick in which the ratio of both factors amounts to about 6:1. This relationship is being further studied. M.V.C.

Proportion clay particle sizes to improve final product. H. G. SCHURECHT AND JOHN REID. *Brick & Clay Record*, **95** [5] 18–19 (1939).—The results of a series of studies made on a shale used for the manufacture of heavy clay products are presented. By proportioning the various sizes of clay particles, the best size distribution for clay can be found, and the desired properties in the finished product can be obtained. Results are plotted by means of triaxial diagrams. J.J.H.

PATENTS

Brick-wall construction. C. S. BROWN. U. S. 2,243,069, May 27, 1941 (Dec. 20, 1938).

Cavity-wall construction and brick and blocks therefor. W. SMALL AND COLTHURST, SYMONS, & CO., LTD. Brit. 536,431, May 28, 1941 (Dec. 4, 1939).

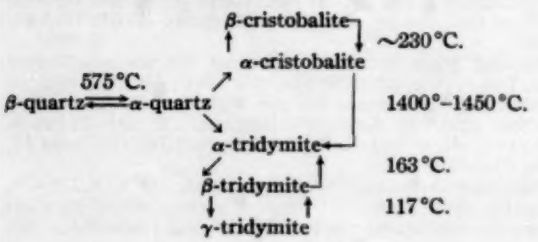
Manufacture of artificial stones with high porosity. JÁNOS ALBERT. U. S. 2,243,369, May 27, 1941 (Aug. 26, 1939).—The method consists in preparing a mortar containing substantially kieselguhr, lime, and water, adding aluminum salt dissolved in sufficient water to raise the water content of the mortar above 70%, pouring the mortar in molds, and hardening in steam.

Refractories

Examination of raw materials to be used in the manufacture of siliceous refractories. G. MALQUORI AND A. GIANNONE. *Rend. Accad. Sci. Napoli*, **9**, 83–87 (1939).—The following tests were carried out: chemical analysis, refractoriness, petrographic studies, and thermodilatometric analysis by means of Chevenard's registering differential dilatometer (*Rev. Mét.*, **23**, 92 (1926)). The results obtained in studying nine siliceous materials are given in the following table:

Sample No.	SiO_2 (%)	P.C.E.	Appearance
1	98.82	35–36	Quartzose rock with large crystals
2	99.07	35–36	" " " " "
3	98.91	35	
4	96.74	34–35	Quartzite with basal cement
5	97.13	35	" " " "
6	96.17	34–35	" " " "
7	97.72	35–36	Cryptocrystalline
8	92.15	29–30	" "
9	96.38	34	Contains chalcedony and opal

The transformations taking place on heating and cooling are shown in the following diagram:



The linear expansion during the transformation of β-cristobalite to α-cristobalite is 1.05%, of β-quartz to α-quartz 0.77%, and of γ-tridymite to β-tridymite to α-tridymite 0.26%. V.S.DEM.

Firebrick in the steel industry. A. E. DODD. *Refrac. Jour.*, **17** [3] 99 (1941); *Claycraft*, **14** [6] 147–50 (1941).—D. considers only fire-clay refractories, excluding those used in blast furnaces. The life of gas-producer refractories varies from several months to 2 to 3 years, depending upon the design of the producer and the type of coal used; iron oxide, lime, and alkalis are the chief slagging agents. The brick linings of gas flues should be able to withstand the disintegrating action of CO, inasmuch as the CO content of the gases averages about 30%. In checkerwork, constructions which promote a turbulent flow of the gas tend to fill up with dust and thus lose some of their efficiency. Where two or three ladles are required to empty a furnace, the life of the ladle linings will usually vary considerably due to the tendency of the last ladle filled to receive the larger part of the slag. In such cases, the life of the first and second ladles is 25 to 30 heats while that of the third ladle is 10 to 15 heats. Other factors affecting the life of ladle linings are as follows: (1) the thickness of the skull, i.e., a thick skull resulting from a dull heat tends to shrink away from the lining while a thin skull tends to adhere to the brickwork and must be pried loose, thus damaging the brick; and (2) the size of ingots cast which determines the length of time that the metal and slag are in contact with the refractory. B.C.R.+G.A.K.

Samuel Pollock Harbison. ANON. *Bull. Amer. Ceram. Soc.*, **20** [6] 210–13 (1941).

History of development of the refractories industry in the United States. ARTHUR F. GREAVES-WALKER. *Bull. Amer. Ceram. Soc.*, **20** [6] 213–18 (1941).—19 references.

Insulation of the reverberatory furnaces of the Krasnouralsk copper smelter. A. A. BORETSKIĬ AND I. S.

NAUMOV. *Tsvetnye Metally*, **1940**, No. 3, pp. 73–77.—Cu smelting at the Krasnouralsk plant is carried on in two reverberatory furnaces using pulverized fuel and handling dross having a temperature of 600° to 650°. The chief lining material was Dinas brick, but large heat losses occurred due to cracks and fissures. The furnace arch was insulated with a mixture of 90% zonolite and 10% water glass. The sealing cement contained 50% finely ground zonolite, 25% glass fines, and 25% water. The walls were insulated with a mixture containing 70 quartz river sand, 14 refractory clay, 10 water-glass solution (1:1), and 6% asbestos. The capacity of solid charge increased from 3.16 to 3.24 tons per 24 hr., but the greatest saving obtained was in a reduction of the specific fuel consumption from 16.83 to 14.55%. B.Z.K.

Measurement of the thermal conductivity of insulating brick. L. BEUKEN. *Wärme- & Kälte-Tech.*, **40** [11] 161–63 (1938).—The measurement of thermal conductivity generally requires numerous apparatus and equipment. B. describes a method which makes it possible to determine the thermal conductivity of insulating brick in a simple and easy manner. The ball method of Nusselt is used, but the arrangement of the ball and the other equipment has been greatly modified. From the insulating brick are made two half balls 120 mm. in outside diameter; these are hollowed out to 60 mm. diameter. This hollow ball of insulating brick is placed between two chrome-steel ball shells. An electric heating element is arranged in the inner shell. The measurement of the difference in temperature between the outside and inside of the insulating brick is done by means of thermoelements. The complete ball is placed in an electric resistance furnace, the temperature of which is held constant while the heating element is so regulated that a difference in temperature of about 30° to 50°C. results between the outside and the inside of the brick. The thermal conductivity can be calculated from the formula $Q = 2\pi\lambda \frac{t_i - t_a}{1/d_i - 1/d_a}$, where Q = energy supply in watts, $t_i - t_a$ = difference of temperature, and d_a and d_i = outside diameter and inside diameter, respectively, of the insulating brick. See "Heat...," *Ceram. Abs.*, **17** [9] 312 (1938). W.L.

Pouring-pit refractories: I and II. EVERETT C. HITE AND GILBERT SOLER. *Brick & Clay Record*, **95** [5] 54–56; [6] 52–55 (1939).—Refractories commonly used in the pouring pit include ladle brick, sleeve brick, stopper heads, nozzles, runner brick, hot tops, and mold plugs. A detailed description and a discussion of the application of pouring-pit refractories and the factors that affect their life are given. Illustrated. 5 references. J.J.H.

Precipitation of second-grade (silumin) alumina from the mother liquor of the Tikhvin aluminum plant. K. E. MANOĬLOV AND A. A. BENGLYANTS. *Tsvetnye Metally*, **1939**, No. 8, pp. 94–96.—Experiments were made on a laboratory scale using a 1.5- to 2-liter carbonator to precipitate the alumina from the mother liquor. Precipitation was carried out by passing in a gas containing 12 to 15% CO_2 for 4 to 12 hr. and at temperatures up to 85°. The mixture was then passed over a horizontal filter and washed once with two parts of water and then with three parts of water by weight of the alumina. Precipitation at 75° to 85° in 4 to 12 hr. proceeded without any difficulties, and the precipitates were easily washed. If the precipitation under these conditions is complete, the final product will contain 1.5% or more of alkali which cannot be washed out. If the precipitation is only 90 to 92% complete, the final product will contain about 0.55 to 0.60% alkali. In practice, the precipitation should be carried out in 4 to 8 hr. at a temperature of 75° to 78° so as to give 3 to 5 gm. per liter of alumina in the residual solution. B.Z.K.

Production of alumina at the Tikhvin alumina plant. N. S. ALEKSEEV. *Tsvetnye Metally*, **1939**, No. 8, pp. 89–93. B.Z.K.

Refractories for open hearths: I. EVERETT C. HITE AND GILBERT SOLER. *Brick & Clay Record*, **95** [2] 54–57 (1939).—The development of the open-hearth furnace is reviewed, and the effect of various feeders on the life of refractories as used in the furnace is pointed out. A detailed description of the basic open-hearth process with the type of refractories used in the hearth and back, front, and end walls is given. **II.** *Ibid.*, [3] 59–60.—Refractories used in the downtakes, slag pockets, and checker chambers of the basic open-hearth furnace are described and discussed. **III.** *Ibid.*, [4] 54–55.—The use of insulation in various parts of the basic open-hearth furnace is discussed. The acid open-hearth process is described, and the various refractories used in the construction of the furnace are discussed. Illustrated. 8 references. J.J.H.

Resistance of refractory materials to abrupt changes in temperature. A. GIANNONE. *Metallurgia Ital.*, **32** [1] 10–12 (1940).—The scaling and cracking of refractory materials subjected to abrupt changes of temperature depend on numerous conflicting factors. G. lists these factors as (1) expansion of the material, (2) discontinuity in the thermal-expansion curve, (3) thermal conductivity, and (4) elasticity and mechanical resistance. He considers indefinite an element of surface of a wall of constant thickness and that a determined temperature gradient exists between the two faces, the isotherms resulting being parallel to the wall face, a hypothesis seldom discussed. Resistance to changes in temperature is favored by (1) moderate and, especially, uniform expansion, (2) high thermal conductivity, (3) low elasticity, (4) good mechanical resistance, and (5) high porosity. Beneficial factors are granulometric distribution and the presence of a certain quantity of glass. K.R.

Stability of the lining of converters of copper smelters. A. A. BODAZHAN. *Tsvetnye Metally*, **1940**, No. 10–11, pp. 66–75.—B. gives a résumé of observations on the stability of the lining of a Pierce-Smith converter at a copper smelter in Russia over an extended period of time. B.Z.K.

Use of refractory materials of high thermal conductivity in ceramics. FRIEDRICH HELAN. *Zprávy České keram. společnosti*, **16** [1–2] 45–49 (1939).—Materials with high heat conductivity are used in ceramics for the production of saggers, in the construction of muffles, and for furnaces where the ware must not have direct contact with gases. Sikarbid is a material with high heat conductivity which improves heat economy and shortens the firing process. Refractory metal alloys are used for closed metal trucks in tunnel kilns where the ware must be protected from the direct action of gases; metal alloys are also used for refractory pipes for circulating heating systems in tunnel kilns. M.V.C.

Utilization of magnesium silicates for the production of refractories. A. S. BEREZHNOĬ. *Zhur. Priklad. Khim.*, **13**, 800–21 (1940).—The investigation of the dehydration, setting, porosity, and specific gravity of materials fired at different temperatures showed that a practically complete dehydration takes place when serpentines are fired to 900° and talc is fired to 1000°, resulting in volume changes of the hydrosilicates. Curves of porosity changes indicate that, depending on the firing temperature, maximum values are observed at 900° for serpentines and at 1000° for talc. Serpentines fired at 900° are recommended as an addition, and those fired at 1400° are recommended as the basic material for the production of refractories. Investigations of the properties of forsterite briquettes prepared from mixtures of different rocks and caustic magnesite fired at different temperatures showed that the firing temperature of forsterite refractories should not be under 1600°. Additions to the batch are not advisable. Several flow sheets were worked out for the production of forsterite refractories from olivinite, dunite, serpentines, etc. Forsterite ware of a considerably reduced porosity (11.5%) can be obtained from serpentines by preliminarily preparing forsterite briquettes. Service tests demonstrated that unfired forsterite refractories can be used expediently for lining the walls of open-hearth furnaces (over the slag line), of reheating furnace hearths, and of cupola furnaces used for dolomite. Magnesium silicates can also be used as additions in the production of other refractory materials (from chromite, magnesite, and dolomite). P.B. & E.S.

PATENTS

Artificial magnesite. CHARLES HART. Can. 395,795, April 15, 1941 (March 14, 1940). G.M.H.

Extraction of alumina. T. R. HAGLUND. U. S. 2,244,194, June 3, 1941 (Aug. 3, 1937).—In the recovery of aluminum values from bauxite, the process comprises passing a caustic leach liquor capable of dissolving alumina, under conditions of elevated temperatures and superatmospheric pressures, upwardly through a reaction zone containing a mass of subdivided bauxite, agitating the bauxite positively, thereby producing entrainment in the liquor of sludge particles formed in the process, and withdrawing the resulting pregnant liquor from an upper point in the reaction zone together with entrained fine sludge particles.

Manufacture of refractory blocks. CORNING GLASS WORKS. Brit. 536,279, May 21, 1941 (Jan. 3, 1939).

Porous refractory and process of manufacture. J. D. MORGAN (Cities Service Oil Co.). U. S. 2,243,219, May 27, 1941 (June 25, 1938).—A refractory composition comprises finely ground zircon bonded by the reaction products resulting from the reaction thereon of about 6% by weight of the zircon of phosphoric acid and about 2% by weight of chromic acid.

Producing refractory linings of centrifugal casting molds. HEINRICH PROJAHN (U. S. Pipe and Foundry Co.). U. S. 2,246,063, June 17, 1941 (Nov. 16, 1938).—A process for the production of refractory linings of rotary molds for use in centrifugal casting consists in introducing into a mold casing loose, dry, granular, refractory material, forming a granular lining by rotating the mold casing to distribute the material and to hold it in place by centrifugal force only, and forming at the inner surface of the granular lining, during the rotation thereof, a zone having greater resistance than the rest of the lining to the washing-away effect of the metal to be cast, the zone being formed by applying a binding agent to produce increased cohesion between the particles of the innermost layer of the granular lining.

Production of composite refractory articles. HARTFORD-EMPIRE CO. Brit. 536,173, May 21, 1941 (Sept. 7, 1939).

Production of an improved refractory material. J. G. STEIN & CO., LTD., AND J. F. HYSLOP. Brit. 536,302, May 21, 1941 (Dec. 14, 1939).

Pure alumina production. A. S. BURMAN. Can. 396,285, May 6, 1941 (June 7, 1937). G.M.H.

Refractory. N. P. PITT, A. C. HALFERDAHL, AND F. E. LATHE (Canadian Refractories, Ltd.). U. S. 2,245,297, June 10, 1941 (Oct. 19, 1934).—A fired refractory composition comprises, as basic constituents, magnesia and 21 to 35% of lime and acid constituents including silica and a small amount of a stabilizing oxide, the basic and acid constituents being in chemically effective base-acid ratio between 2.23 and 2.77 to form calcium silicates of which tricalcium silicate is predominant, and is fired at a temperature rendering the product substantially nonhydrating.

Refractory. S. F. WALTON (Oxolon Co.). U. S. 2,246,226, June 17, 1941 (Sept. 23, 1936).—A batch mixture for forming refractory bodies comprises a refractory grog and a bonding mix for bonding it, the mix comprising a high alumina hydraulic cement and a crystalline fused aluminum oxide toward which the cement is reactive at ordinary ceramic temperatures to form a refractory bond having a higher melting point than the hydraulic cement, the proportions of the bonding mix being approximately 50% cement and 50% aluminum oxide.

Refractory block casting method. H. T. SMYTH (Corhart Refractories Co.). Can. 395,842, April 15, 1941 (Sept. 28, 1939; in U. S. Jan. 3, 1939). G.M.H.

Refractory product and method of making. H. P. HOOD (Corning Glass Works). U. S. 2,244,777, June 10, 1941 (June 1, 1937).—The method of forming refractory materials comprises mixing stannic oxide with a small amount of a copper-containing compound, molding the mixture under pressure into a body of desired shape, and sintering the body.

Refractory-wall construction. J. H. HENZEL AND E. T. HEINRICH. U. S. 2,243,339, May 27, 1941 (June 10, 1939).

Thermal insulator and refractory. HUKUZIRO INABA. Japan. 132,631, Oct. 13, 1939; *Chem. Abs.*, **35**, 3408 (1941).—A mixture of extremely weathered quartzite powder, kieselguhr, and silica cement is moistened with water, molded, air-dried, boiled in aqueous Na silicate, dried, and fired at high temperature.

Terra Cotta

Importance of impregnation in ceramics. JOSEF MATĚJKA. *Zprávy České keram. společnosti*, **16** [1–2] 24–29 (1939).—Impregnation of ceramic objects is generally a necessary precaution by means of which the properties of the product are improved. The impregnating agent is applied either by dipping or painting. Its action is usually of a physicomechanical nature but is sometimes chemical in that a reaction takes place between the surface constituents and the agent. In heavy ceramics, impregnating agents reduce water permeability, increase heat insulation, and prevent efflorescence on the surface of objects; the agents must be of good quality. Among the many forms are those containing silicate (water glass); fluate impregnating agents; agents containing hydroxide in the colloidal state, e.g., aluminum; iron hydroxide; and organic luting agents (paraffin, soap solutions, and coal distillation products). The artificial luting of roof tile may also be considered an impregnation; the dried tile is dipped in clear limewater which forms a fine layer of calcium carbonate on the surface of the tile from the calcium hydroxide. M.V.C.

Requirements for ceramic radiators and their testing. F. BRADTKE. *Ber. Deut. Keram. Ges.*, **22** [2] 33–48 (1941).—About 30 years ago an attempt was made to use ceramic radiators for central heating but without success. The reason for this was that cast-iron radiators fulfilled the requirements of central heating so completely that it seemed superfluous to consider other materials. The restrictions of the first Four-Year Plan showed the desirable characteristics of ceramic materials. After initial failures in 1938, radiators of a usable form and with the required efficiency were produced. In installing ceramic radiators it is necessary that their essential dimensions be equal to those of standard cast-iron radiators because heating engineers and architects have standardized these dimensions and especially because ceramic and cast-iron radiators should be interchangeable. In the standardization of cast-iron radiators there are four over-all heights and four distances between pipe connections, or 16 sizes of radiator. As these standard dimensions cannot be attained exactly with ceramic radiators, a variation of ±5% is allowed. This forces the producers to sort their radiators according to size and to furnish a radiator to fit an exactly prescribed length. For maximum efficiency, a radiator section should occupy a length of at least 70 mm.; a length of 60 mm. is required for a cast-iron section. Heat is given off from a radiator partly by convection and partly by radiation. The efficiency is expressed by the k value, k being the heat in Cal. per hr. given off by 1 sq. m. of heating surface with a temperature difference of 1°C. Increasing the height of a radiator decreases the convection. The depth has a greater effect; if it is increased, both the convection and the radiation are decreased; thus every unnecessary increase in the heating surface, inside or outside the sections, decreases the k value. The radiator should also convey the heat to the room in such a way that the upper zone is not heated too much compared with the middle and lower zones. Considering both the heat given off and its distribution, unnecessarily large surfaces of a single section and too narrow spaces between sections

should be avoided. Points in design are as follows: (*a*) the weight of radiators and of their water content should be kept low, (*b*) too much air should not be allowed to accumulate in them, and (*c*) the walls should be no thicker than required for strength. According to the regulations, radiators may be made of any hard ceramic material and may be glazed or unglazed. The following three tests are prescribed for strength and tightness: (1) The radiator is filled with water of not over 20°C. and is subjected for 30 min. to a cold water test with a maximum pressure of 7 atm., the pressure being increased to the maximum at the rate of 1 atm. per sec. (2) After the pressure test, the radiator is emptied and filled, when cold, with steam at 110°C. (0.5 atm.); it is kept at this pressure for 30 min. For radiators for use with hot water, the test is made at 110°C. and 4 atm. (3) After cooling, test 1 is repeated. Ceramic radiators are required to have a *k* value not more than 0.3 Cal./m.²/°C. lower than that for a standard cast-iron radiator of the same depth and having the same distance between connections. This requirement has been met by radiators of three different firms. Two of them have four columns and one has three. A table shows the dimensions and results of tests on 16 ceramic radiators. High *k* values were obtained with radiators weighing 16 to 18 kgm. per m.² of heating surface, about 10 kgm. per m.² lighter than standard cast-iron radiators. Illustrated.
W.H.H.

PATENTS

Flowerpot for water-cultured plants. W. P. MUNSELL. U. S. 21,820, June 3, 1941 (Nov. 20, 1940); reissue of original 2,205,303, June 18, 1940 (June 9, 1938).

Making mosaic. J. A. MADALA. U. S. 2,246,052, June 17, 1941 (Nov. 22, 1940).

Scoring and breaking device for tile. EDMUND ENGLEKE. U. S. 2,246,351, June 17, 1941 (Oct. 10, 1939).

Whiteware

Action of acids and alkali solutions on ceramic bodies. R. RIEKE. *Ber. Deut. Keram. Ges.*, **21** [12] 477–87 (1940).—Test conditions must often be more severe than those encountered in actual service to obtain results within a reasonable length of time. In testing the effect of acids and alkali solutions on ceramic bodies the severity of the tests may be increased by increasing the exposed surface, by increasing the concentration of the solutions, or by increasing the temperature. Test methods which seem especially useful or which have been in use for a long time are considered. In most cases, the material is granulated and a fraction is taken which passes one sieve and is retained on the next. In the clay industry, the sample is frequently 100 gm. between 64- and 120-mesh, while O. Kallauner and R. Barta propose 1 gm. between 900- and 1600-mesh. R., with the cooperation of N. Preslawski, applied both methods and an absorption test to 11 samples of stoneware, etc. When using the finer material, the loss in weight was 4.29 to 5.90%, with the exception that porcelain showed a loss of 4.10% and soapstone only 0.57%. The corresponding values for the coarser material were 0.17 to 0.71%, with 0.26% for porcelain and no loss observed for soapstone. The order of excellence of the samples was not exactly the same according to the two test methods, and no relation between absorption and susceptibility to attack by acid could be observed. Tests were also made by increasing the time of boiling in H_2SO_4, in the Kallauner and Barta test, from 1 to 2 and 3 hr., with a resulting increase in loss of weight. Rieke and Schade (*Ceram. Abs.*, **10** [5] 363 (1931)) discussed the solubility of ceramic materials in hydrofluoric acid and the determination of the muilite content of porcelain by this means. Concentrated phosphoric acid is believed to dissolve most ceramic materials except quartz, but the attempt to determine the quartz content of porcelain by this method was unsatisfactory, the values obtained being always lower than the actual quartz content. W. Steger ("Stability. . . ," *Ceram. Abs.*, **17** [5] 191 (1938)) developed a method for determining resistance to alkalis which is similar to that of Kallauner and Barta for resistance to acid. R. applied Steger's method to the same materials tested for acid resistance and found much greater losses in weight.
W.H.H.

Agreement of ceramic bodies and glazes as a function of their respective structures. R. LECUIR. *Compt. Rend.*, **211** [11] 207–209 (1940).—It has previously been established that, as a rule, the agreement of the expansion coefficients of a body and a glaze during cooling is sufficient assurance of their later agreement; the determination of these coefficients therefore makes it possible to predict later agreement. In the case of nonagreement, crackling is the inherent defect of transparent glazes, while scaling or flaking takes place in opaque glazes. In his attempts to find a means of modifying the expansion coefficients, L. found that, if a glaze crackles on a given body, any modification in glaze structure giving (for the same structure of the body) a greater heterogeneity of the glaze tends to suppress the crackling. If a glaze flakes on a certain body, any modification in its structure which effects (for the same structure of the body) a greater homogeneity of the glaze has the tendency to suppress flaking. If, however, it is necessary or preferable to alter the composition of the body, the shrinking of the material can easily be effected by the composition without changing any other factor in the manufacture. For a given firing temperature, the addition of a component which is a solvent for the other constituents of the body will increase shrinking and oppose crackling of the glaze. If a component is added which is not easily attacked by the constituents of the body, shrinkage will be reduced and flaking of the glaze suppressed. In the latter case, to reduce the shrinkage of the body, it is preferable to add vitrified and broken-up body rather than silica which might have the effect of a flux and increase shrinking.
M.H.

Feldspar-dolomitic glazes. LADISLAV FEJLEK. *Zprávy České keram. společnosti*, **16** [1–2] 50–55 (1939); see "Dolomite...," *Ceram. Abs.*, **19** [9] 218 (1940).
M.V.C.

Fog insulators for outdoor substations. WALTHER ESTORFF AND WERNER WEBER. *Elektrotech. Z.*, **61**, 645–48, 669–73 (1940).—Developments and changes in the design of petticoats or rain sheds of porcelain transformer bushings are discussed. Nine different designs, their dimensions for 120-kv. insulators, and their influence upon the corona and flashover behavior in air, fog, or rain and under dirt condensation are described. The equipment used for artificially covering insulators with lignite ash layers and moisture is shown. With dirt and moisture condensation the flashover values of some insulators dropped to 21% of their regular value, while for others under the same conditions the flashover value dropped to only 50%. This difference is due to more favorable petticoat designs, i.e. larger creepage surface and air space under the petticoats. These specially designed insulators are known as fog insulators. Illustrated.
L.E.T.

Glazes without lead or boron. W. STEGER. *Ber. Deut. Keram. Ges.*, **22** [3] 101–103 (1941).—In seeking to make glazes without lead or boron it is important to recognize their functions in the batch. Both have an important fluxing effect. Boric acid directly decreases the expansion with temperature. Indirectly, boric acid is such a good flux that the amount of alkali oxides (which tend to increase expansion) may be reduced. Boric acid has the special property, common to no other material, of preventing devitrification of glazes. This has been overlooked in preparing formulas for lead- and boron-free glazes. S. introduced fluorine because it has a fluxing action nearly like that of boric acid and because it forms, with other materials, eutectics with melting points only slightly lower than those formed with boric acid. Fluorine in combination with silicates has a strong devitrifying effect. S. observed this at low temperatures but seldom

at slightly higher glost-fire temperatures. K. JACOB. *Ibid.*, pp. 103–105.—J. recommends the following formula for a white opaque glaze, for Seger cones 07*a* to 05*a*:

$$\left.\begin{matrix}0.110\ K_2O\\0.290\ Na_2O\\0.046\ CaO\\0.554\ ZnO\end{matrix}\right\}\ 0.247\ Al_2O_3\quad 2.020\ SiO_2$$

In the whiteware industry, firing to cone 02*a* is preferred, and an approved transparent glaze for this temperature has the following formula:

$$\left.\begin{matrix}0.200\ K_2O\\0.246\ Na_2O\\0.198\ ZnO\\0.150\ CaO\\0.086\ BaO\\0.120\ MgO\end{matrix}\right\}\ 0.26\mathcal{C}\ Al_2O_3\quad 2.166\ SiO_2$$

The zinc oxide is reduced by the introduction of the earth alkalis, calcium, barium, and magnesium. The glaze is suitable as a covering glaze for underglaze colors of all tones, including the bright Victoria green and pink colors. As far as has yet been indicated by investigation, the preparation of lead- and boron-free glazes for a temperature range of cones 05*a* to 02*a* presents greater difficulties than that for temperatures over cone 1*a*, because the unfavorable viscosity and high expansion with temperature must be overcome. The introduction of fluorine compounds improves the viscosity, but at firing temperatures of cones 05*a* to 02*a* the introduction of fluorine increased the tendency toward crazing; it was increased to a greater extent with calcium fluoride than with sodium silicofluoride. JULIUS BIDTEL. *Ibid.*, pp. 105–107.—The greatest difficulty with lead- and boron-free glazes is that they are more viscous and require higher firing temperatures. Many plants for art ceramics cannot fire above 900° to 960°C. Only the plants which are in position to raise their firing temperature can utilize these glazes.

W.H.H.

Importance of glaze color of porcelain transmission line insulators in flashover danger. W. WEBER AND M. PFEIFER. *Elektrotech. Z.*, **61**, 561–65 (1940).—It has long been observed that flashover on line insulators occurs more frequently at sunrise and that this phenomenon is caused by moisture condensation upon the cold insulators from fog and morning dew. Temperature measurements on specially designed porcelain cylinders showed that dark-glazed insulators are warmed much faster by sun rays and therefore keep dry and free from corona or flashover. Tests were carried out during the winter months on sunny days, and the results are tabulated as so-called color factors as follows: black 1.00, brown 0.95, green 0.81, white 49, and silver finish 0.45. The latter was produced by firing a platinum coating over white-glazed porcelain cylinders. The white glaze used in Europe for many years has now been abandoned for dark brown. Another reason for glazing line insulators with a dark-colored glaze is that salt condensation which occurs near the sea coast can be more easily detected. 3 diagrams. L.E.T.

Mullite porcelain: I. S. KONDO, S. SUZUKI, AND S. SATO. *Jour. Japan. Ceram. Assn.*, **48** [570] 261–71 (1940).—The manufacture of mullite porcelain fired at comparatively low temperatures, such as cones 10 to 14, was studied. Sixteen specimens were prepared from kaolin, secondary kaolin, quartz, and feldspar, with and without the addition of alumina and talc, under various conditions of forming and at different firing temperatures. The compressive strength, tensile strength, resistance to quenching, and specific electrical resistance at elevated temperatures were studied. The alumina contents of the bodies were rather low for mullite porcelain (34.86 to 61.82%). Three specimens contained only quartz and feldspar as flux, and the source of the mullite was clay. To three specimens 20 to 40% of Al_2O_3 was added. Ten specimens contained quartz, feldspar, and 5 to 20% of talc as flux; 10 to 15% of Al_2O_3 was added. All specimens were fired at Seger cones 9, 11, 13, and 14. The conclusions are as follows: (1) When alumina is substituted for clay, the strength and thermal durability are improved gradually within certain limits. (2) When clay is replaced by talc and the alumina content is kept constant by adding alumina, the increase of the magnesia content due to talc reduces the tensile and compressive strength, but the specific resistance and thermal durability are improved. If the alumina content is increased at the same time, the decrease in strength can be prevented. (3) If the alkali content due to feldspar is reduced, tensile strength is improved. The effect of the alkali due to feldspar on the tensile strength is much stronger than that of magnesia. II. *Ibid.*, [572] 376–82.—The mullite content and specific gravity of 16 specimens fired at cone 14 were determined. A microscopic study was made. The results are as follows: (1) The mullite content is increased markedly by the addition of talc. (2) Increase of the mullite content increases the specific gravity especially in feldspar bodies but only slightly in talc bodies. (3) When the mullite content is increased, compressive strength also increases except in feldspar bodies. (4) The thermal durability is closely related to the microstructure; the bodies which consist of homogeneous mullite crystals and no residual quartz or porous structures are resistant to thermal shock. Y.K.

Sanitary porcelain (construction, characteristics, and tests to determine the most suitable composition): II. R. RIEKE AND K. HEINSTEIN. *Ber. Deut. Keram. Ges.*, 21 [3] 81–128 (1940).—Tests were made, in regard to composition and characteristics, on nine samples of sanitary porcelain of German manufacture and four pieces of American hotel china. Tests on the German ware showed no great differences. One manufacturer used a higher proportion of quartz and less kaolin; two others replaced part of the feldspar with calcite. The color of the ware was nearly white; the fracture was slightly vitrified. In each case, the absorption by boiling was below 1%. The bending strength was between 482 and 765 kgm. per cm.^{2}, only two samples giving values above 600 kgm. per cm.^{2}. The specific gravity was between 2.45 and 2.54, with two values over 2.50. Between 500° and 600° C., the expansion with temperature showed more or less the effect of the transformation of the quartz. Some samples showed small irregularities also at 200°C., indicating a slight formation of cristobalite. The coefficient of expansion was between 47 and 58 $\times$ 10^{-7} (between 20° and 760°C.). Analyses were carried out for two samples of American hotel china, the two fragments differing greatly. One contained only 13.2% feldspar, and the other contained 20.7%. Both contained small amounts of lime. The color and fracture of the samples were very similar to those of hard porcelain (white and strongly vitrified). Absorption by the vacuum method was below 0.15% for all four samples; the bending strength was 582 to 703 kgm. per cm.^{2}; the specific gravity was 2.46 to 2.49. The expansion, determined for only one sample, showed a very clear quartz effect between 500° and 600°C. The average coefficient of expansion with temperature was 62.5 $\times$ 10^{-7} (between 20° and 760°C.). The American products differed from the German by a high quartz content. Analyses showed the use of purer raw materials. No essential difference between German and American products could be determined; differences in composition resulted in only superficial differences in characteristics. From the low absorption, high bending strength, specific gravity, and composition of sanitary porcelain, its similarity to hard porcelain can be recognized. Hard porcelain is essentially different from sanitary porcelain in regard to expansion. The temperature expansion curves of sanitary porcelain show, between 500° and 600°C., a clear quartz effect. The chief difference between sanitary porcelain and hard whiteware lies in the low absorption and the high strength of sanitary porcelain, which is to be attributed to its higher feldspar content. This investigation showed the need of the vacuum method to determine the absorption. To determine the kaolins and clays suitable for making sanitary porcelain, 8 different bodies were prepared from 2 kaolins and 4 clays. The most important and necessary

characteristics were a clear firing color, a very good liquefaction, good suction speed, and high green strength. In most cases it is not possible to obtain all the required characteristics with a single clay; a mixture must be used. To brighten the firing color and raise the stability on firing, a certain part of the clay substance is introduced as kaolin, whose selection is determined by the characteristics of the clay. Both kaolins but only one of the clays proved suitable for sanitary porcelain. In another series of tests, it was found that when the clay substance remained constant an increase in quartz content caused an increase in bending strength, expansion, and specific gravity and a decrease in shrinkage on firing. With bodies rich in feldspar and with little quartz, a glassy body is formed in which a small amount of free quartz is still present. The mechanical characteristics of these bodies are not very good; the fragments appear to be too brittle. The addition of quartz remedies this, but too much quartz gives the characteristics of whiteware. An increase in the content of clay substance, when the quartz content is kept constant, increases the specific gravity. This shows that silicic acid, resulting from the decomposition of the clay substance, is dissolved; more free quartz remains undissolved, and the body attains better stability on firing. Within the limits 45 to 50 clay substance, 25 to 35 quartz, and 20 to 30% feldspar, bodies could be fired to Seger cone 10 and had the characteristics of sanitary porcelain. The addition of grog to a sanitary porcelain body causes an improvement in the slip, viz., an increase in the speed of suction and a decrease in the shrinkage on drying. The green strength, however, is decreased. All the samples fired to Seger cone 10 showed scarcely any differences. If the bodies were fired to Seger cone 9, they could still be described as sanitary porcelain as the absorption was 1.8%; although the bending strength was lower, it could be increased by the addition of grog. The particle size of the quartz plays a large part in this sanitary porcelain. If the quartz is very large, the bodies do not become dense at Seger cone 10, and the expansion is very high; the specific gravity is increased and the bending strength of the fired product decreases considerably. If the quartz is too fine, the stability during firing suffers. Tests show that with these bodies as with hard porcelain a certain amount of quartz is dissolved in the feldspar, giving the fired ware the required characteristics. The ratio of kaolin to clay has a great effect on a sanitary porcelain body, especially with regard to the slip. With equal clay substance, bodies with increasing clay and decreasing kaolin content show an increase in dry shrinkage and a decrease in suction speed. The absorption of test pieces fired to Seger cone 10 decreased with increasing clay content. The variation of the ratio of kaolin to clay is a useful means of changing the characteristics of sanitary porcelain bodies. Sanitary porcelain may be defined as a dense nearly white ceramic material, transparent in thin layers, for making sanitary objects. The composition varies between the following limits: clay substance 40 to 50, quartz 25 to 40, feldspar 20 to 30, and calcite up to 2.5%. The firing temperature lies below Seger cone 11, so that the material is a soft porcelain. Other characteristics are as follows: porosity not over 1%, specific gravity 2.45 to 2.54, bending strength 500 to 800 kgm. per cm.^{2}, average expansion between 20° and 760°C. 47 to 60 $\times 10^{-7}$. The high strength and density of the material indicate that it is a substitute material for new fields. Pipes and radiators have already been made of it. It is cheaper than hard porcelain, and the body is easily prepared. The firing temperature is 150°C. lower than that for hard porcelain. Ease of pouring and adaptability to firing in tunnel kilns permit a more economical production. Even large pieces of sanitary porcelain can be made with regularity. For Part I see *Ceram. Abs.*, **20** [6] 150 (1941). W.H.H.

Substitute raw materials for preparing glazes. HANS LEHMANN. *Ber. Deut. Keram. Ges.*, **22** [2] 49–54 (1941).—Previous attempts to make glazes free from lead and boron yielded only wartime solutions, i.e., as soon as the market became normal the old approved glazes were used again. At the beginning of this war, however, a committee was formed to determine whether the war experience would suggest any new development for future use. The relation between chemical composition and viscosity of whiteware glazes has been discussed by H. Lehmann, K. Endell, and H. Hellbrügge (*Sprechsaal*, **73**, 307–12, 321–26 (1940)). It was found that, in making glazes free from or poor in lead and boron, it was practical to increase the variability of the RO and R_2O portion. An increase in the alkali content by the introduction of alkali silicates, as proposed by Alzner ("Glazes . . . ," *Ceram. Abs.*, **20** [5] 120 (1941)), was an improvement. The tendency of these glazes to settle may be remedied by adding electrolytes. Zinc, barium, and magnesium compounds, in not too great amounts, are widely used in the new type of glazes. L. gives formulas for glazes fired to cones 1a to 5a. The proposal of Steger ("Lead-free . . ," *ibid.*) that fluorine compounds be introduced has been opposed for various reasons, although experiment shows that the addition of fluorspar markedly improves the viscosity of frits free of lead and boron. Cullet may be used in the preparation of glazes. See *Ceram. Abs.*, **20** [6] 150 (1941). W.H.H.

PATENTS

Ceramic burner unit for broilers. S. N. BOBO (R. P. Sniffen). U. S. 2,244,045, June 3, 1941 (Aug. 31, 1939).

Composition of high dielectric constant. S. KONDO (Tōkyō Kōgyō Daigakutyo). Japan. 132,611, Oct. 12, 1939; *Chem. Abs.*, **35**, 3407 (1941).—A mixture of TiO_2, alkali or alkaline earth halide, and 1 or more of CuO, ZnO, BaO is molded and fired at Seger cone 12 or 15.

Cordierite porcelains. SIN-ITIRO OGAWA (Toki Sikenziotyo). Japan. 132,801, Oct. 23, 1939; *Chem. Abs.*, **35**, 3408 (1941).—A framework consisting mainly of SiC is fired, mixed with cordierite as a binding agent, molded, and fired at 1250° to 1410° to make thermally conductive refractory material for use as a substitute for metal in stoves, etc.

Cranks and like supports for pottery during firing. J. WEDGWOOD & SONS, LTD., AND N. WILSON. Brit. 536,082, May 14, 1941 (April 10, 1940).

Electric insulating porcelain. S. KONDO AND SIN-ITI SUZUKI. Japan. 132,515, Oct. 7, 1939; *Chem. Abs.*, **35**, 3408 (1941).—Steatite, Korean kaolin or clay, feldspar, $MnCl_2$, Fe_2O_3, and CaO are wet-mixed in proportions to give Na_2O 0.01 to 0.05, K_2O 0.01 to 0.05, CaO 0.01 to 0.1, MgO 0.80 to 0.95, Al_2O_3 0.07 to 1.00, SiO_2 1.20 to 3.00, Mn_2O_3 0 to 0.01, and Fe_2O_3 0.005 to 0.01 mol., molded, and fired at 1300° to 1500°.

Making molded ceramic articles. GENERAL MOTORS CORP. Brit. 535,950, May 7, 1941 (Nov. 29, 1938); addition to 472,110, Sept. 29, 1937 (Jan. 25, 1935).

Spark plugs. SOC. DE CONSTRUCTION D'APPAREILS MÉCANIQUES ET ELECTRIQUES POUR AUTOMOBILES. Brit. 536,358, May 21, 1941 (March 18, 1939).

Spark plugs for internal-combustion engines. PLESSEY CO., LTD., G. C. GAUT, AND H. F. COLLENDER. Brit. 536,460, May 28, 1941 (Dec. 9, 1939).

Thermally conductive refractory porcelains. SIN-ITIRO OGAWA (Toki Sikenziotyo). Japan. 132,800, Oct. 23, 1939; *Chem. Abs.*, **35**, 3408 (1941).—Suitable proportions of artificial cordierite (which has low coefficient of expansion), SiC (a good thermal conductor), and clay (which is plastic) are mixed, molded, dried, and fired at 600° to 1410°.

Equipment and Apparatus

Critical review of dust-sampling methods employed in Witwatersrand gold mines. J. DE V. LAMBRECHTS. *Jour. Chem. Met. Mining Soc. S. Africa*, **41** [6] 209–40 (1940).—L. critically discusses the technique used on the Witwatersrand for taking and examining dust samples by the konimeter and the thermal precipitator. He concludes that the konimeter gives an entirely reliable indication of conditions at the time of sampling, but that the

thermal precipitator is more reliable and useful over an extended period. L.W.V.

Determination of constitution diagrams with X rays. C. S. BARRETT. *Jour. Applied Physics*, **12**, 385–94 (1941). —X-ray diffraction is of value in determining constitution diagrams, particularly for alloys. A.P.

Drying with infrared radiation. H. A. CLARK. Read before Industrial Gas Section, American Gas Assn., Toledo, March, 1940; *Ind. Heating*, **7** [5] 438, 440–47 (1940).—C. explains the principles of drying with radiation, especially by infrared rays in the range 14,000 to 6500 a.u., and discusses the technical advantages connected with it. A higher temperature is reached in a shorter time as the heat penetrates better into the material to be dried. The concentration of the rays is important; it is determined by design and efficiency of reflectors and by the distance of the radiating lamps from the material. A concentration on the material of 1.2 watts per sq. in. produces a temperature of 200°F. in 5 min.; a concentration of 6 watts per sq. in. produces a temperature of 500°F. in the same time. The rate at which the radiated heat is absorbed by the material is of equal importance; a white surface will reach a temperature of 275°F. in 15 min., while the same surface painted black will reach 350°F. in the same time. The drying time depends also on the type of enamel used; lacquers dry by evaporation of the thinner, synthetics dry by evaporation of the thinner and by polymerization, and oleoresins dry by evaporation of the thinner, by polymerization, and, which is most important, by oxidation. While infrared radiation shortens the drying time for the two first groups, not much time can be gained by drying oleoresins in this way as their drying is determined by the oxidation, which requires a certain time. The use of different types of coatings is discussed. M.H.

Electron diffraction observations of surface reaction of hydrogen selenide on zinc oxide. M. L. FULLER AND C. W. SILLER. *Jour. Applied Physics*, **12**, 416–19 (1941). —The reaction of hydrogen selenide and pigment zinc oxide at room temperature was investigated with the aid of electron and X-ray diffraction. Zinc selenide forms a coating around the zinc oxide particles, giving a yellow color. After one-tenth of the zinc oxide has been converted, the coating prevents continuance of the reaction. A.P.

Emission spectroscopy and its application in the investigation and solution of problems in ceramics. H. C. HARRISON AND L. B. BASSETT. *Jour. Amer. Ceram. Soc.*, **24** [7] 213–21 (1941).—6 figures, 30 references.

Instrument for studying fine texture of ceramic and other surfaces. F. W. ADAMS, LEE DEVOL, AND H. R. LETNER. *Jour. Amer. Ceram. Soc.*, **24** [7] 229–34 (1941).—8 figures, 3 references.

Removing moisture from compressed air. L. I. BUNCE. *Glass Ind.*, **22** [6] 248–49 (1941).—"Aftercoolers" for removing moisture from compressed air are recommended on the basis of the physical laws involved. A.P.

X-ray diffraction methods. B. E. WARREN. *Jour. Applied Physics*, **12**, 375–83 (1941).—X-ray diffraction is used to study the fine scale structure of matter, to identify crystalline materials, and to determine preferred orientations, particle sizes, strains, and structure randomness. Basic principles and working techniques are described. A.P.

X-ray physics and X-ray tubes. VICTOR HICKS. *Jour. Applied Physics*, **12**, 364–73 (1941).—H. presents the physical background of X rays and describes the design, manufacture, and types of X-ray tubes. A.P.

SEPARATE PUBLICATION

Iceland Spar and Optical Fluorite. H. HERBERT HUGHES. *U. S. Bur. Mines Information Circ.*, No. 6468R, 19 pp. Free.—H. describes the uses, physical properties, and geology of Iceland spar and optical fluorite, the methods by which they are mined, and their occurrence. Statistics on consumption, prices, and markets are also given. See *Ceram. Abs.*, **10** [11] 806 (1931). R.A.H.

PATENTS

Gas atmosphere in electric furnaces. WILLARD ROTH (Westinghouse Electric & Mfg. Co.). U. S. 2,246,322, June 17, 1941 (Sept. 21, 1938).

Method and apparatus for manufacturing pottery ware. W. J. MILLER. U. S. 2,243,880, June 3, 1941 (March 1, 1929; March 20, 1936).

Process and apparatus for producing cylindrical ceramic tile. C. N. BROOKS. U. S. 2,245,181, June 10, 1941 (Oct. 10, 1938).

Rotary ball mill. E. G. SUNDFELT. Can. 395,697, April 8, 1941 (March 30, 1939; in U. S. April 9, 1938). G.M.H.

Tile-cutting machine. C. A. MARTIN. Can. 395,816, April 15, 1941 (Oct. 13, 1939). G.M.H.

Kilns, Furnaces, Fuels, and Combustion

Influence of mixing of gas and air on the speed of combustion. W. TRINKS. *Ind. Heating*, **7** [10] 928–36 (1940).—T. reviews and discusses two German investigations (K. Rummel, Influence of Mixing Process on the Combustion of Gas and Air in Furnaces (Einfluss des Mischvorgangs auf die Verbrennung von Gas und Luft in Feurerungen), Verlag Stahleisen, 1937; H. Schwiedessen, *Stahl & Eisen*, January, 1940) on the mixing of air and gas in a burner and its effect on the resulting flame and combustion process. A theoretical investigation of the process showed that, with most burners, diffusion is of secondary importance in mixing while turbulence is of prime importance. Experiments made in a specially developed combustion (mixing) chamber or tunnel, based on the theoretical considerations, led to the following conclusions: If gas and air enter the furnace on two sides of a wall (tongue), the mixing, i.e., the required combustion, space grows with the thickness of the separating wall. If one medium (gas or air) enters surrounded by the other medium, the necessary mixing space is reduced by giving the inner medium a whirl. Inclination of gas and air jets to each other reduces mixing, and consequently the flame length, considerably. Normal (right-angle) impact of an imperfect gas-and-air mixture against a wall causes quick completion of mixing; the same effect is obtained by flow through a grid or checkerwork. The mixing is influenced mainly by (1) the velocities of the gas and air jets, (2) the angle between the gas and air jets, and (3) the thickness of both jets. Burners designed according to these three factors are described. According to T., gas burners should be considered not really as burners but as gas and air mixers which the gases leave in a more or less completely mixed state. If the mixing is perfect, the flame (or heat) is very short and intense. If it is not perfect, the remainder of the mixing and combustion must take place in the furnace; in this case the length of the flame is also influenced by the shape of the combustion and heating chamber. The burner must therefore be carefully selected according to the flame desired for a given combustion or heating process. M.H.

Viscosities of several common gases between 90°K. and room temperature. HERRICK L. JOHNSTON AND KENNETH E. MCCLOSKEY. *Jour. Phys. Chem.*, **44**, 1038–58 (1940).—Data for H_2, air, O_2, N_2, NO, N_2O, CO_2, and CH_4 are given and compared with previous results. R.A.G.

SEPARATE PUBLICATION

Analyses of Washington Coals. H. F. YANCEY AND M. R. GEER. *U. S. Bur. Mines Tech. Paper*, No. 618, 81 pp. Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 15¢. Supplement to *ibid.*, No. 491. R.A.H.

Hydrogenation and Liquefaction of Coal. H. H. STORCH, L. L. HIRST, C. H. FISHER, AND G. C. SPRUNK. *U. S. Bur. Mines Tech. Paper*, No. 622, 110 pp. Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 20¢.—Results obtained in the investigation of the production of liquid fuels from coal by the hydrogenation process are described. A review of the literature, a description of an experimental plant, and liquid-phase assays of some typical bituminous, subbituminous, and lignite coals are given. R.A.H.

Geology

Aluminous materials found in the vicinity of Messina. GAETANO LABRUTO. *Ricerca Sci.*, **11** [5] 328–31 (1940).—A new kaolinic material from the province of Messina has the following chemical composition: SiO_2 59.12, Al_2O_3 28.90, Fe_2O_3 1.32, CaO 0.75, MgO 0.08, $Na_2O + K_2O$ 1.24; moisture 0.37, loss at 900°C. 8.31%, pH 7.5, and specific gravity 2.569. Brick of this material fired at 1100°C. showed a negligible reduction of area, without either deformation or cracking. To prepare brick from this material 55.47% water was needed; Rieke plasticity was 3.83, linear reduction was 5.71%, and the modulus of rupture on bending after air drying was 62.9 and after drying at 110°C. 99.2. A silicoaluminous material from Lipari Island has the following chemical composition: SiO_2 52.10, Al_2O_3 26.79, Fe_2O_3 0.18, CaO 0.89, MgO 0.27, K_2O 0.92, Na_2O 1.20; moisture 10.91, loss on calcination 6.74%, and specific gravity 2.294. Kaolinite in the air-dried material equals 66.94% and in the calcined sample (600°C.) 75.30% This material has a firing temperature of 900°C. and fuses at 1600° to 1650°C., always remaining white. Trachytic tufa from Lipari Island has the following physical characteristics: specific gravity 2.3429, apparent specific gravity 0.8812; apparent porosity 45.45%, actual porosity 37.60%; particle-size distribution of the granules 88.95% of 0.2 mm., 6.26% of 0.05 mm., 3.26% of 0.01 mm., 0.55% of 0.005 mm., and 0.98% of less than 0.005 mm.; maturing temperature 1140°C. The chemical composition is SiO_2 73.45, TiO_2 0.10, Al_2O_3 14.99, Fe_2O_3 1.10, FeO 0.85, MnO 0.62, MgO 0.12, CaO 0.76, K_2O 1.73, and Na_2O 3.20; moisture 0.38; loss on calcination 3.30%; pH 7.53. After 235 days it fixed 31.41% of CaO. Various tests show that this trachytic tufa can be used as a decolorant in the glass industry, as pozzuolanic material, and as an addition to Portland cement clinker. V.S.DEM.

Application of the phase rule to crystal systems. D. BALAREV. *Monatshefte Chem.*, **71**, 30–45 (1938).—B.'s theory that crystal systems are built up by little crystallites grown together is applied to a system of the type

$$A \rightleftarrows B + C$$

Crystal Crystal Gas W.N.

Ceramic raw materials in the neighborhood of Bechyně. MIROSLAV PETRŮ. *Zprávy České keram. společnosti*, **16** [1–2] 39–44 (1939).—Raw materials from the region of Bechyně vary in composition and physical and chemical properties and can be used for many purposes in ceramics. The rational analysis of one clay of this region gave an average composition of 80% kaolinite, 20% quartz, and a small amount of feldspar and muscovite. The melting point lies between Seger cones 34 and 35. The body is rather porous. This clay is suitable for grog products and the production of grog tile. The rational analysis of another clay shows 88% kaolinite and 7% quartz, the residue being orthoclase, muscovite, and biotite. The melting point is between Seger cones 28 and 31. This clay fires yellow in oxidizing firing to Seger cone 1*a* and turns brown at higher temperatures. In reducing firing, the clay fires a beautiful gray-white. It is used in the manufacture of industrial stoneware, slabs, etc. M.V.C.

Comparative grading and chemical tests on Turkish, Rhodesian, and Transvaal chromites. R. BASKIND. *Bull. Minerals Research Lab., Univ. Witwatersrand*, No. 6, pp. 25–27 (1940).—Tests were carried out to ascertain whether crushed hard lumpy chromite from Transvaal and washed concentrates from friable ores could be blended so as to have a grading analysis similar to that of either Rhodesian or Turkish material. A minimum of 47% Cr_2O_3 was specified. The tests showed that this is possible, and B. suggests that some of these blends might be acceptable to refractory manufacturers. L.W.V.

Concentration tests on chromite: I. R. BASKIND. *Bull. Minerals Research Lab., Univ. Witwatersrand*, No. 6, pp. 5–10 (1940).—B. found that a friable chromite containing about 8% by weight of silicates gave satisfactory concentrates, after crushing, by jigging, tabling, flotation, or magnetic separation, although the recovery was never high. **II.** J. LEVIN. *Ibid.*, pp. 11–20.—L. obtained satisfactory concentrates from a number of different samples by crushing and washing or tabling. L.W.V.

Division of Mineralogy and Geology at the Zwinger State Porcelain Gallery, Dresden. Special exhibit, "Saxon ceramic raw materials and their utilization." WALTHER FISCHER. *Ber. Deut. Keram. Ges.*, **22** [1] 29–30 (1941).—A complete view of the ceramic industry is given by an exhibit of raw materials and structural clay products as well as the porcelains which have long been on display in the Dresden museum. This supplementary exhibition is in the Division of Mineralogy and Geology and is the beginning of a future division of applied mineralogy and geology. A special exhibit shows the derivation of kaolin from the mother rock and the relation between chemical and mechanical composition. The most important clay minerals are demonstrated with their X-ray diagrams, showing the significance of X-ray analysis with regard to the course of the firing process. Examples of color change on firing and of shrinkage are also demonstrated. The most important raw materials for the Saxon brickyards and products made from them, together with diagrams concerning the distribution of the ceramic raw materials and ceramic plants, complete the exhibit. The production of hard whiteware is shown by raw materials, photographs of processes, and many intermediate products from the unfired condition to the finished ware. The production of structural products is similarly illustrated. W.H.H.

Consolidation settlement under a rectangular load distribution. M. A. BIOT. *Jour. Applied Physics*, **12**, 426–30 (1941).—B.'s general theory is applied to calculation of the settlement through consolidation of a soil loaded uniformly on an infinite strip of constant width, with particular reference to the nature of the settlement at the edge of the loaded area. A.P.

General theory of three-dimensional consolidation. M. A. BIOT. *Jour. Applied Physics*, **12**, 155–64 (1941).—Settlement of soils and clays under load is caused by a phenomenon whose mechanism is in many cases identical with the process of squeezing water out of an elastic porous medium. The mathematical physical consequences of this viewpoint are established, and simple applications are used as examples. A.P.

Importance of electron microscopy for mineralogical investigations. W. EITEL. *Fortschr. Mineral., Krist., & Petrog.*, **23**, CXV–CXX (1939).—The apparatus and its applicability to ceramics (clays) are described. W.N.

Kaolin deposits in the province of Sassari. AURELIO SERRA. *Ricerca Sci.*, **11** [5] 322–27 (1940).—The deposit was estimated to be approximately 500,000 tons. This material is used in the manufacture of refractories, in white cement, and in the glass industry. V.S.DEM.

Magnesites from Elba Island. A. GIANNONE. *Rend. Accad. Sci. Napoli*, **9**, 88–91 (1939).—Magnesites from Crocetta and Stabiali have the following chemical composition: loss on calcination 44.53, 46.12; SiO_2 11.59, 9.01; R_2O_3 1.37, 0.63; CaO 1.13, 0.98; MgO 40.08, 42.02; and undetermined 1.30, 1.20%, respectively. These high SiO_2 magnesites were compared with low SiO_2 magnesites from Quercetto Val d'Esta, Montefuroli, and Castiglioncello (Tuscany) whose respective chemical compositions are as follows: loss on calcination 53.19, 52.69, 51.87; SiO_2

0.31, 0.90, 2.15; R_2O_3 0.93, 1.81, 1.21; CaO 1.38, 1.12, 2.26; MgO 43.09, 42.18, 41.41; and undetermined 1.10, 1.20, 1.10%. Thermal analysis, thermodilatometric analysis carried out with Chevenard's registering differential dilatometer (*Rev. Mét.*, **23**, 92 (1926)), and X-ray analysis confirm D'Achiardi's conclusion (*Atti Soc. Toscana sci. nat.*, **20** (1903)) that the SiO_2 is mostly free and amorphous in the form of opal and chalcedony. V.S.DEM.

Measurement of the so-called force of crystallization. C. W. CORRENS. *Fortschr. Mineral., Krist., & Petrog.*, **23**, CV–CVIII (1939).—Two actions, volume expansion and linear growth, must be regarded. The volume expansion is observed in crystallizing water. The pressures are not great. The linear growth of an octahedral crystal of potassium alum shows the validity of the principle of Riecke and the differences in the surface tensions of the different planes of the crystal. W.N.

Microdetermination of bivalent iron in rocks and silicate minerals. M. SHIOIRI AND S. MITUI. *Mikrochim. Acta*, **3**, 291–99 (1938).—A microanalytical determination of bivalent iron in rocks and silicate minerals, which can be performed simply and quickly, is described. Samples of 3 to 30 mgm. (depending on the FeO content expected) are sufficient for obtaining correct results. The apparatus and the method of analysis are described in detail. The sample is decomposed by heating with hydrofluoric and sulfuric acid in an atmosphere of steam and carbon dioxide; the resulting solution is titrated with $^1/_{50}$ *N* permanganate solution in the presence of a sufficient quantity of boric acid. The titration is carried out in a manner resembling the J. P. Cooke macroprocedure. Test analyses of ferrous ammonium sulfate, silicate minerals, and rocks show that the principle of the macroprocedure may also be applied to microanalytical technique. The method yields reliable results. W.N.

New methods of cleaning glass sands. JOHN DASHER AND O. C. RALSTON. *Bull. Amer. Ceram. Soc.*, **20** [6] 187–95 (1941).—5 figures, 4 references.

Predicting behavior of clay. RALPH E. GRIM. *Brick & Clay Record*, **97** [6] 20–22 (1940).—G. describes research work at the Illinois Geological Survey, discusses the three types of clay minerals, and explains the effect of each in various clays. The quantity and size of nonclay minerals in a clay are important factors which control clay properties. The clay minerals have the property of carrying basic ions, which, under certain conditions, are exchangeable for other ions without changing the structure of the clay minerals. Montmorillonite has the greatest capacity for base exchange, and kaolinite has the least. It is generally believed that the exchangeable ions are held on the surface of the clay-mineral particles. The properties of clays vary according to the identity of the exchangeable base present. It should be possible to treat many clays (those containing clay minerals with a reasonably high base-exchange capacity) with the proper ion to obtain the properties most desired. See "Relation . . .," *Jour. Amer. Ceram. Soc.*, **22** [5] 141–51 (1939). J.J.H.

Sillimanite-corundum rock—a metamorphosed bauxite from Namaqualand. C. B. COETZEE. *Trans. Roy. Soc. S. Africa*, **28** [3] 199–205 (1940).—This unusual rock contains SiO_2 26, Al_2O_3 66 to 67, and TiO_2 5.5% and is believed to have been formed by static metamorphism of a dominantly aluminous sediment, probably a bauxite. Illustrated. L.W.V.

South African raw materials as substitutes for imported earths in connection with oil refining. G. ARMSTRONG SMITH. *Jour. Chem. Met. Mining Soc. S. Africa*, **41** [5] 197–208 (1940).—An active form of MgO produced from crude magnesite waste by calcining at 700°C. was found to be nearly as suitable as highly active imported bentonite for the decolorizing of oil wastes in reconditioning processes. It is possible to regenerate the MgO by calcination at a low temperature. Exfoliated vermiculite is inactive. L.W.V.

Strontium. L. SANDERSON. *Can. Mining Jour.*, **61** [11] 726–28 (1940).—The two primary sources of strontium are the minerals celestite and strontianite. Great Britain is the principal source of the former, and there are important deposits in Canada. Germany is the greatest source of strontianite. Potential sources of these minerals are the United States, North Africa, Russia, and France. Celestite is usually quarried in lumps and hand-shaped. Strontianite is mined by overhead stoping. Salts of strontium are obtained mainly from celestite. Strontium is used in metallurgy (1) as a deoxidizer and purifying agent for copper, (2) as a copper and a cadmium alloy, and (3) in the form of strontianite, as a cleanser for iron and steel. G.M.H.

Theory of the oriented precipitations of ionic crystals on each other. I. N. STRANSKI AND L. KRASTANOV. *Monatshefte Chem.*, **71**, 351–64 (1938); **72**, 76 (1939).—Theoretical considerations on the problem of crystal growth are presented. W.N.

Weathering of feldspar. W. v. ENGELHARDT. *Fortschr. Mineral., Krist., & Petrog.*, **23**, CXX–CXXIII (1939).—The weathering of feldspar does not lead to alkali-free residual pseudomorphs. The feldspar completely dissolves on weathering, and new minerals, such as the clay minerals, form from the ionic solutions. See *Ceram. Abs.*, **18** [10] 280 (1939). W.N.

SEPARATE PUBLICATIONS

Alunite. J. R. THOENEN. *U. S. Bur. Mines Repts. Investigations*, No. 3561, 48 pp. Free.—T. describes a survey of the known alunite deposits in Ariz., Calif., Colo., Nev., Utah, and Wash. Alunite is of interest as a possible source of both aluminum and potash. R.A.H.

Cationic Reagents in the Flotation of Silica from Gypsum Ores. Metallurgical Division Progress Report No. 43. J. BRUCE CLEMMER AND F. D. DEVANEY. *U. S. Bur. Mines Repts. Investigations*, No. 3553, 12 pp. Free.—The importance of gypsum in industry is explained, and tests made to determine the value of cationic reagents for the flotation of silica and discoloring impurities from gypsum ores are described. R.A.H.

Chromite Deposits of the Eastern Part of the Stillwater Complex, Stillwater Co., Mont. J. W. PEOPLES AND A. L. HOWLAND. *U. S. Geol. Survey Bull.*, No. 922–N, 45 pp. (1940). Supt. of Documents, Govt. Printing Office, Washington, D. C., 1941. Price 40¢.—Chromite occurs in a belt of ultramafic rocks composed chiefly of pyroxene and olivine, 27 miles long, on the northeastern margin of the Beartooth Mountains in Stillwater and Sweetgrass counties, Mont. The outcrop of these igneous rocks ranges in width from a quarter of a mile to a mile. Chromite occurs near the center in layers and lenses parallel to the layering of the complex throughout most of the length of the belt. Results are given of a detailed study of the chromite deposits on the Benbow claims of the Chromium Products Corp. on Little Rocky Creek. A brief reconnaissance of the deposits on the west side of Stillwater Canyon is presented. Trenching on the Benbow claims made it possible to trace segments of a tabular body of chrome ore with an aggregate length of 5660 ft. for a distance of 9000 ft. along the strike. As all of the ore is approximately half chromite, it must be concentrated. The possible tonnage of the ore above the Eclipse adit, the lowest opening on the property, is calculated to be nearly 1,500,000 short tons of massive ore and 345,000 tons of disseminated ore. On the east side of Stillwater Canyon, chromite-rich bands of varying thicknesses alternate with bands of rock containing disseminated chromite for a distance of about 1200 feet along the strike. Available data are insufficient for an estimate of tonnage, but the area appears promising for the development of a large tonnage of millable ore. A geologic map of the district is included. R.A.H.

Chromite Deposits of the Pilliken Area, Eldorado Co., Calif. F. G. WELLS, L. R. PAGE, AND H. L. JAMES. *U. S. Geol. Survey Bull.*, No. 922–O, 43 pp. (1940). Supt. of Documents, Govt. Printing Office, Washington, D. C., 1941. Price 35¢.—The Pilliken chromite area in Eldorado Co., Calif., near the western edge of the foothills of the Sierra Nevada, has produced more than 10,000 tons of ore. The chromite deposits occur in dunite, an olivine rock, which constitutes the lower part of an elongated sill-

like body of ultrabasic rocks that dips steeply to the east and is 4 miles long and 0.7 mile wide. In places, the grains of chromite, which contain from 30 to 50% of chromic oxide, are disseminated in the dunite; elsewhere they are concentrated in layers which may be as much as 2 or 3 ft. thick. The ore mined in the past has come from these layers of higher-grade ore. The future of the area depends on the utilization of the lower-grade disseminated ore, which must be concentrated. The reserves of this type of ore are roughly estimated to be 10,000 tons containing over 50% of chromite, 540,000 tons containing 20 to 50% of chromite, and 4,120,000 tons containing 10 to 20% of chromite. A geologic map of the district is included. R.A.H.

Chromite Deposits in the Seiad Quadrangle, Siskiyou Co., Calif. G. A. RYNEARSON AND C. T. SMITH. *U. S. Geol. Survey Bull.*, No. 922-J, 25 pp. (1940). Supt. of Documents, Govt. Printing Office, Washington, D. C., 1941. Price 30¢.—Chromite was discovered in the Klamath Mountains in the northeastern part of the Seiad Quadrangle, Siskiyou Co., Calif., during the last war. The chromite deposits occur in and are generally related to intrusive masses of olivine-rich rock. Most of the ore bodies are tabular masses, from a few feet to a few hundred feet in length, which strike approximately parallel to the elongation of the enclosing peridotite. Reserves in the district, as estimated from known outcrops, are believed to be approximately 125,000 tons with an average content of 35% chromite. At prices of $20 to $25 a ton, however, it is unlikely that any of these deposits can be profitably worked. There are in addition an estimated 200,000 tons containing 20% chromite. These ores can be concentrated to yield a higher-grade product. A preliminary geologic map of the district is included. R.A.H.

Chromite Deposits in the Sourdough Area, Curry Co., and the Briggs Creek Area, Josephine Co., Oreg. F. G. WELLS, L. R. PAGE, AND H. L. JAMES. *U. S. Geol. Survey Bull.*, No. 922-P, 35 pp. (1940). Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 30¢.—The Sourdough, or Baldface, chromite area is on Baldface Creek in the rugged, mountainous region of southwestern Oregon. It is 31 miles west of U. S. Highway 199. The chromite occurs in a large body of peridotite near its contact with sedimentary rocks, which are probably Jurassic in age. The peridotite is partly saxonite and is largely serpentinized. Chromite crystals are disseminated through most of the dunite, and, locally, the crystals are aggregated in streaks or layers separated by barren layers. Some layers or lenses of massive chromite range from a few inches to several feet in thickness. The chromite that might possibly be mined is all in one zone about 2400 ft. long and 965 ft. deep. The rapid changes in the tenor of the rock make any estimate of tonnage a guess, but the area may contain between 50,000 and 100,000 tons of millable ore. The Briggs Creek chromite deposits are on Chrome Ridge in Josephine Co. There was considerable activity in this area during World War I. The known deposits are in the southern part of a sill-like peridotite mass intruded in a group of rocks which may be the regionally metamorphosed equivalents of the Jurassic rocks in the Sourdough area. At least 75% of the peridotite in the Briggs Creek area is saxonite; the remainder is dunite. The chromic oxide content of the chromite ranges from 39 to 55%. No large tonnage of ore assaying as much as 10 to 20% chromic oxide has been developed. Geologic maps of the two districts are included. R.A.H.

Empire Mineral Resources and Their Relation to the War Effort. S. J. JOHNSTONE. 23d Streatfield Memorial Lecture. Institute of Chemistry, Gt. Britain and Ireland, 1940.—Although no nation is entirely self-sufficient in its deposits of the fifty or more minerals of commerce, the British Empire is probably more favorably endowed in this respect than any other political unit in the world. The subject is considered under three main headings: (1) the British Empire's mineral wealth compared with that of the remainder of the world in the production of minerals essential for industry and war; (2) Empire minerals and metals, their production, uses, and trade, with details of recent overseas developments to meet increased demands occasioned by the war; and (3) Government assistance to the mining industry in the overseas Empire. The second section deals with mineral fuels, iron and ferro alloy minerals, base metal ores, precious metals and stones, minerals for chemical industries, industrial earths and clays, and miscellaneous nonmetallic materials. The third section gives a critical survey of the extent and limitations of the various forms of assistance available to the government departments and to prospectors. Statistical tables and graphs are included showing world and British Empire outputs for 1935 and 1938, the value of British Empire mineral output in 1935, and world and Empire production of various minerals for the period 1919 to 1938. K.W.W.B.

Froth Flotation and Agglomerate Tabling of Micas. JAMES E. NORMAN AND R. G. O'MEARA. *U. S. Bur. Mines Repts. Investigations*, No. 3558, 14 pp. Free.—The results of an investigation of the beneficiation of muscovite, biotite, lepidolite, and vermiculite are given. R.A.H.

PATENTS

Floating fluorspar values from fluorspar ore. ALUMINUM CO. OF AMERICA. Brit. 535,800, May 7, 1941 (April 19, 1939).

Preparation of magnesium silicate, talcum, and talclike compounds. OCEAN SALTS (Products), LTD., AND B. A. ADAMS. Brit. 535,853, May 7, 1941 (Sept. 20, 1939).

Chemistry and Physics

Analysis of platinum-iridium ores. W. H. C. LOVELY. *Chem. Eng. & Mining Rev.*, **33** [391] 199 (1941).—L. gives a method for the analysis of platinum ores, determining thallium, iridium, palladium, osmium, platinum, ruthenium, gold, and rhodium. B.C.R.

Application of the hydrogen-bridge theory to sorption from solution by silica gel. ALBERT L. ELDER AND ROBERT A. SPRINGER. *Jour. Phys. Chem.*, **44**, 943 (1940).—Data are given on the sorption of various organic acids from organic solvents and from water by silica gel. A semiquantitative explanation of the results depends on the relative extent of hydrogen bridging by the solute, solvent, and gel and on the size and shape of the acid molecules. R.A.G.

Applied nuclear physics. R. D. EVANS. *Jour. Applied Physics*, **12**, 260–70 (1941).—Following the discovery of artificial radioactivity and the rarer stable isotopes of the light elements, the forty-year-old field of applied nuclear physics has found greatly increased usefulness in chemistry, metallurgy, radiology, geology, physiology, and medicine. A.P.

Colorimetric estimation of iron with sodium salicylate. R. O. SCOTT. *Analyst*, **66** [781] 142 (1941).—In estimating small amounts of iron with a photoelectric absorptiometer, S. found the thiocyanate method unsatisfactory, due to the difficulty in measuring the color, although the color seemed to remain stable. A satisfactory method consists of treating a solution containing 0.05 to 0.55 mgm. of Fe_2O_3 with 4 ml. of 1:1 HCl followed by 5 ml. of 1% sodium salicylate solution; 1:1 NH_4OH is added, drop by drop, until the amethyst color of the iron complex changes to yellow, after which 2 more drops are added; 1:1 acetic acid is added, drop by drop, until the solution becomes pink; 5 ml. in excess are then added. The solution is made up to 50 ml., and the color absorption is determined. Either ferric ammonium sulfate or ferrous ammonium sulfate, in which the iron is oxidized with hydrogen peroxide and boiled, may be used for primary standards. The fol-

lowing ions, present in 50 ml., may occur in the amounts shown without causing appreciable error: Ti 0.3 mgm., Al 3.5 mgm., Mn 12.0 mgm., SiO_2 3.0 mgm., PO_4^{---} 4.0 mgm., F^- 0.1 mgm., and Cl 2.0 mgm. B.C.R.

Crushing strength of some ceramic materials on the basis of single substances. EUGEN RYSCHKEWITSCH. *Ber. Deut. Keram. Ges.*, **22** [2] 54–65 (1941).—The strength of materials at the highest possible temperatures is studied. The strongest ceramic materials are hard porcelain, stoneware, and soapstone, having a strength of over 7000 kgm. per cm.^{2} when cold. Information in regard to strengths at elevated temperatures is meager. R. tested Al_2O_3, synthetic $MgO \cdot Al_2O_3$, ZrO_2 (with a slight addition of MgO), ThO_2, and BeO. These were made up into 6 mm. cubes and fired to cone 40. The test cubes could be heated while in position in the press. As the sintered alumina could be heated to more than 1000° higher than the tungsten carbide pyramids placed next to the steel plates of the press, blocks of alumina were inserted between the pyramids and the test cube. By the use of the pyramids, the pressure on the plates was reduced to $^1/_{10}$ that on the test cube. When the surfaces above and below the test cube were lubricated, higher and more concordant values for the crushing strength were obtained. A test lasted only a few seconds. When the limiting pressure was reached, the cube exploded with a loud report. Above 1000°C., the explosion became less marked, and failure was more like plastic yielding. R. gives tables and diagrams showing the change in compressive strength with rise in temperature to 1500° or 1600°C. Although beryllia showed the lowest strength (8000 kgm. per cm.^{2}) at 20°C., it had the highest strength above 1400°C. In all cases, there was a continuous decrease in strength with increasing temperature and no indication of any maximum at about 1000°C. as was found in previous tests on firebrick. It is therefore to be expected that the crushing strengths would be considerably higher at low temperatures. W.H.H.

Determination by volumetric analysis of titanium and vanadium in argillaceous rocks. WILHELM DAUBNER. *Ber. Deut. Keram. Ges.*, **22** [3] 107–10 (1941).—Titanium is determined by the oxidation of trivalent titanium to tetravalent by a solution of calcium permanganate. The titanium is generally present as titanium oxide, and this must first be changed to soluble titanium sulfate by fusing with calcium pyrosulfate. Vanadium is determined by reducing vanadium pentoxide (V_2O_5) to vanadyl oxide (V_2O_4) by boiling hydrogen iodide in the presence of normal sulfuric acid and measuring the precipitated iodine by a thiosulfate solution. D. gives a complete analysis of the action of titanium and vanadium compounds in the determination of other elements. W.H.H.

Electrical conductivity of alumina at high temperatures. A. R. SHULMAN. *Zhur. Tekh. Fiz.*, **10**, 1173–82 (1940).—S. investigated the electrical conductivity of alumina at temperatures of 700° to 2200°K. by a method in which the plasma of the gas discharge was used as one of the electrodes. The material was prepared by mixing the alumina with nitrocellulose in amyl acetate, after which it was calcined on W at 1700°C. in an atmosphere of "wet" hydrogen for 5 min. Chemical analysis of the admixtures could not be made. Between the temperatures of 1200° and 1500°, the temperature curve of the electrical conductivity showed a break. This break is not due to structural changes or settling but to the conductivity of the alumina. B.Z.K.

Electron diffraction study of hydrous oxides amorphous to X rays. HARRY B. WEISER AND W. O. MILLIGAN. *Jour. Phys. Chem.*, **44**, 1081 (1940).—The oxide gels may be grouped into two classes, crystalline and amorphous, according to their diffraction patterns. Crystalline oxides include ferric oxide, Al_2O_3, gallium, titanium (Ti^{IV}), and probably beryllium oxides. Amorphous oxides, amorphous in the sense that glass is amorphous, are Cr, Si, columbium (Cb^V), and tantalum (Ta^V)oxides. R.A.G.

Equilibria in the systems Na_2O–Al_2O_3–H_2O and Na_2O–SiO_2–H_2O at 25°C. J. W. SPRAUER AND D. W. PEARCE. *Jour. Phys. Chem.*, **44**, 909 (1940).—The phase diagram shows marked differences in several places from results reported by others. In particular, the field of stability of $Na_2O \cdot SiO_2 \cdot 6H_2O$ is at Na_2O concentrations lower than those reported by Harman. Evidence of the existence of $3Na_2O \cdot 2SiO_2 \cdot 11H_2O$ at stable equilibrium is presented. R.A.G.

Optical, spectrographic, and radioactivity studies of zircon. J. H. MORGAN AND MARIANNA L. AUER. *Amer. Jour. Sci.*, **239** [4] 305 (1941).—The results obtained are presented. The variations in physical properties of zircon may be due to a breakdown of the crystal lattice by the action of radioactive elements included at the time of crystal formation. It is suggested that the type of zircon present in a granite is governed by the concentration of uranium in the magma at the time of formation of the zircon crystals. A spectrographic analysis of 24 samples of zircon showed the presence of zirconium, silicon, hafnium, yttrium, cerium, lead, iron, and titanium. B.C.R.

Physics in 1940. T. H. OSGOOD. *Jour. Applied Physics*, **12**, 84–99 (1941).—O. attempts to summarize, in easily understandable language, the high lights of recent work in a few important fields. A.P.

Physics of upward drilling. F. W. PRESTON AND J. C. TURNBULL. *Amer. Jour. Sci.*, **239** [2] 92–106 (1941).—A theory of "upward drilling" by gas-bearing solutions through a ceiling of a solid phase is developed on the basis of experiments with ice as the solid phase and various fluids and solutions as the liquid phase. The composition of the gas phase is unimportant. According to this theory, there is one particular size of bubble that is most active and thus one definite size of cavity that tends to progress most rapidly with a particular set of components. The size of cavity is calculated for ice attacked by alcohol, refractories attacked by molten glass, and for rocks attacked by viscous magmas. Good agreement was obtained between the calculated and actual size of the cavities for ice, but in the latter two cases, the agreement was less accurate, though of the proper order of magnitude, because the correct values of the physical constants involved are not exactly known. B.C.R.

Silicic acid gels: X, Time of set of gel mixtures containing high concentrations of mineral acids. CHARLES B. HURD AND RAYMOND W. BARCLAY. *Jour. Phys. Chem.*, **44**, 847 (1940).—The effect of pH and temperature upon the time of set of very acid gels prepared from sodium silicate and either HCl or H_2SO_4 is described. For Part IX see *Ceram. Abs.*, **19** [6] 149 (1940). R.A.G.

Silicon monoxide: I. H. INUZUKA. *Matuda Kenkyu Jiho*, **15**, 161–66 (1940).—Anhydrous silica was heated at 1700° to 1800°C. in a graphite crucible in a vacuum. SiO formed on the surface of the crucible and the electrode. SiO is a dark brown isotropic fine powder with a specific gravity of 2.2, an index of refraction of 1.70 to 1.80, and a lattice constant of 6.4 a.u.; a unit cell contains 8 molecules. A thermal analysis was also made. The absorbed water escapes at 150°C.; it oxidizes gradually up to 900°C. and very rapidly at 950°C. where it changes to SiO_2. The increase of weight by oxidation is 30.4%. **II.** *Ibid.*, pp. 237–41.—The change of SiO by oxidation is investigated by means of X-ray and electron diffraction. Y.K.

Soft X-ray spectroscopy of solids: II, Emission spectra from simple chemical compounds. H. M. O'BRYAN AND H. W. B. SKINNER. *Proc. Roy. Soc.* [London], **A176**, 229–61 (1940).—*K* and *L* emission bands in the soft X-ray region of the spectrum were investigated for halides, oxides, sulfides, boron nitrides and other boron compounds, and carbides. Results are interpreted to give the characteristics of the bands of levels which exist for the valence electrons in the normal state of the substance. The 2*p* bands of oxygen from most oxides indicate considerable interaction between electrons in neighboring atoms. The spectra of the metal ions in oxides are very complex. It is concluded that the oxides consist of singly negative ions and corresponding positive ions with a strong admixture of neutral atoms. SiO_2 has spectra similar to those of a covalent compound such as SiC. A.P.

Systems B_2O_3–PbO, SiO_2–PbO, and P_2O_5–PbO, vitreous and crystallized. E. KORDES. *Fortschr. Mineral., Krist., & Petrog.*, **23**, CXXXVIII–CXXXIX (1939).—The

molecular volume and molecular refraction of the glasses B_2O_3–PbO, SiO_2–PbO, and P_2O_5–PbO are discussed. A Laue diagram shows the hexagonal symmetry of $Pb_3Si_2O_7$ (barysilite). See "Physicochemical . . .," *Ceram. Abs.*, **20** [4] 90 (1941). W.N.

Theory of the plastic properties of solids. F. SEITZ AND F. A. READ. *Jour. Applied Physics*, **12**, 100–18, 170–86 (1941).—The plastic properties of solids may be classified as (*a*) slip, (*b*) creep, (*c*) twinning, (*d*) rupture, and (*e*) fatigue. Each is defined. Experimental material relating to the plastic properties of solids is discussed in relation to the theory it suggests. A.P.

Thermodynamical theory of the tensile strength of isotropic bodies. R. FÜRTH. *Proc. Roy. Soc.* [London], **A177**, 217–27 (1941).—F. developed a new formula connecting the tensile strength of an isotropic body with its melting energy and Poisson's elastic constant which is in good agreement with experiments. A.P.

Time of set of silica gels: V, Effect of alcohols and pH on "heat of activation." L. A. MUNRO AND J. A. PEARCE. *Jour. Phys. Chem.*, **44**, 1024 (1940).—The differences in the behavior of acid and alkaline silica gels are shown in their action toward addition agents, in their time of syneresis, and in their appearance and stability. It is concluded that the gelations of acid and alkaline gels are fundamentally different. R.A.G.

Use of photography in ceramics. L. KOLÁŘSKÝ. *Zprávy České keram. společnosti*, **16** [1–2] 56–59 (1939).—Photochemical methods are used in ceramics for the chemical analysis of raw materials and the rapid determination of the total alkalis by the polarographic method of Heyrovsky. Photography can also be used for the quantitative microscopical analysis of ceramic materials, and it supplements microscopic-petrographic examination of thin sections, e.g., in the production of refractory ware. Photoceramics is a photographic method of reproducing pictures in vitrifiable pigment on porcelain, faience, enamels, and stoneware which are permanent after firing. The technique is based either on the powder method or on the substitution method. See "Photoceramics," *Ceram. Abs.*, **15** [6] 172 (1936); *Bull. Amer. Ceram. Soc.*, **20** [1] 1–4 (1941). M.V.C.

Volumetric determination of silica in blast-furnace slag, Portland cement, and Portland-cement clinker with the aid of *o*-oxyquinoline. P. P. BUDNIKOV AND S. S. ZHUKOVSKAYA. *Zhur. Priklad. Khim.*, **13**, 311–13 (1940).—The application of the *o*-oxyquinoline method to the determination of silica in blast-furnace slag, Portland cement, and Portland-cement clinker was studied. The data obtained by this method, compared with data obtained by the standard method, confirmed its full applicability. The process of analysis is described in detail. P.B. & E.S.

Water glass. BRUNO SCHWEIG. *Glass*, **18** [2] 40; [3] 72 (1941).—S. describes several analytical methods for the determination of SiO_2 and alkali. Complete solution of solid water glass in water at 100° is quite difficult, but it can be effected easily when the water glass is heated in an autoclave under pressure. Solid water glass dissolves quicker in dilute sodium silicate solutions than in pure water. Various industrial uses of sodium silicates are discussed briefly. See *Ceram. Abs.*, **20** [5] 129 (1941). B.C.R.

X-ray studies of silica. KEI-ITI AKIYAMA. *Waseda Applied Chem. Soc. Bull.*, **17** [1] 21–25 (1940).—A. studied the change of silica gel when heated at high temperatures by the X-ray method. An amorphous hydrous silica was heated at 600°C. for 4 hr., and H_2O (about 40%) was evaporated. It was then fired at 900°, 1100°, 1300°, and 1500° for 2 hr. Results were as follows: At 900° it became a white powder but showed no lines. At 1100°, very faint lines appeared. At 1300°C., it sintered slightly and showed lines of cristobalite. At 1500°, it changed to cristobalite completely. No tridymite was observed. Y.K.

BOOK

Modern Theory of Solids. F. SEITZ. McGraw-Hill Book Co., Inc., New York, 1940. 698 pp. + XV, 306 illustrations. Price $7.00. Reviewed in *Jour. Applied Physics*, **12**, 419 (1941). A.P.

PATENTS

Chlorinating titanium-bearing materials. I. E. MUSKAT AND R. H. TAYLOR (Pittsburgh Plate Glass Co.). U. S. 2,245,077, June 10, 1941 (May 4, 1940).

Chlorination of titanium-bearing materials. I. E. MUSKAT AND R. H. TAYLOR (Pittsburgh Plate Glass Co.). U. S. 2,245,076, June 10, 1941 (Dec. 22, 1939). ALPHONSE PECHUKAS (Pittsburgh Plate Glass Co.). U. S. 2,245,358, June 10, 1941 (July 14, 1939).

Fluorescent material. W. A. ROBERTS (General Electric Co.). U. S. 2,245,414, June 10, 1941 (March 14, 1940).—A fluorescent zinc beryllium silicate for gaseous electric discharge lamps containing a source of ultraviolet radiation comprises by weight approximately 60 parts zinc oxide, 40 parts silica, 1 to 10 parts beryllium oxide, and 2 to 10 parts manganese dioxide.

Manufacture of titanium dioxide pigments. NATIONAL TITANIUM PIGMENTS, LTD., I. D. WEBER, AND A. N. C. BENNETT. Brit. 536,208, May 21, 1941 (April 24, 1940).

Reduction of chromates to produce chromic oxide. O. F. TARR AND L. G. TUBBS (Mutual Chemical Co. of America). U. S 2,246,396, June 17, 1941 (June 7, 1938).

General

Activity of the Institute for Glassmaking, Ceramics, Technology, and Testing of Building Materials in the Czech Technical School in Prague. RUDOLF BÁRTA. *Zprávy České keram. společnosti*, **16** [1–2] 30–34 (1939).—B. is the director of the Institute which was founded in 1908 by Joseph Burian. Recent subjects of research in the field of glass and ceramic ware production are listed. M.V.C.

Boiler scale removed chemically. FR. *Emailwaren-Ind.*, **18** [7–8] 16–17 (1941).—Boiler scale has a heat conductivity $^1/_{30}$ that of iron, and a deposit of only a few millimeters on the inside of boilers, pipes, conduits, and condensers causes considerable damage. It may be removed mechanically or by chemical means. A solution of HCl with the addition of a protecting resin (a refined natural resin has been approved, Ger. 548,315) removes the scale without injuring the boiler material. If the boiler scale is composed mainly of $CaCO_3$, it is completely removed: $CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2$. A laboratory test of a sample should be made to determine the composition of the scale. For boiler scale composed mainly of calcium sulfate with silica or silica scale, a different method of procedure is followed: The boiler is treated with a 1 to 2% soda solution at 140° for 24 hr. Conversions take place during this time in the layer of boiler scale. The boiler is then cooled, and the scale is removed by adding acid as before. The acid is emptied out, and the boiler is again treated with the 1 to 2% soda solution at 140° for 24 hr. This treatment is necessary only for boiler scale containing gypsum, which cannot be removed by the acid treatment in the concentration used in practice, although it can be removed at a higher temperature (not above 40°). Commercial 30 to 37% HCl with a specific gravity of 1.15 to 1.19 is obtained in 60-liter flasks; 780 gm. of the resin are dissolved in it in 12 to 24 hr., and the acid is diluted (1:3 to 1:6). The resin has the same protecting action as the materials used in pickling to prevent injury to the metal, and this action is explained. One or two days suffice for removing the scale; the solution is stirred occasionally to accelerate the dissolving process. The CO_2 formed must be conducted off to prevent poisoning. Fire and open flames should be prohibited, and the workers should wear protecting goggles. The acid should not be sprayed on. After the scale is removed, the acid

is drained out and discarded; the boiler is well washed with water and then rinsed with a 1 to 2% soda solution to remove any traces of acid which remain. M.V.C.

Committee on Chemical Data for Ceramists—progress report. ALEXANDER SILVERMAN, *Chairman*. *Bull. Amer. Ceram. Soc.*, **20** [6] 220–21 (1941).

Current needs in industrial research. PHILIP DRINKER. Presented at Third Annual Congress of Industrial Health, Chicago, Jan., 1941; abstracted in *Ind. Med.*, **10** [3] 108 (1941).—Silicosis research has been carried out by L. U. Gardner ("Recent. . .," *Ceram. Abs.*, **19** [8] 205 (1940)). It is now possible to make dust injections in specific cases to determine whether a mixed dust or any specific dust in question will have the same reaction as free silica or asbestos. Further work is being done with industrial groups in Canada regarding the use of aluminum compounds as protective media ("Silicosis . . . XII," *ibid.*, **20** [4] 108 (1941)). K.R.

Development of ceramic ware for the chemical industry. PERCY C. KINGSBURY. *Trans. Amer. Inst. Chem. Engrs.*, **36**, 433–42 (1940); see "New . . .," *Ceram. Abs.*, **19** [2] 48 (1940). H.E.S.

Disability evaluation in silicosis. J. G. BLAISDELL. Presented at Third Annual Congress of Industrial Health, Chicago, Jan., 1941; abstracted in *Ind. Med.*, **10** [3] 108 (1941).—The respiratory tests of McCann were thoroughly investigated and studied with regard to their adaptation to this work. Such tests could evaluate, with fair accuracy, disability in silicosis, as they were adapted to individuals in this investigation. The tests include (1) an estimation of the total pulmonary capacity, including residual air, reserve air, tidal air, and complemental air; and (2) a study of the pulmonary ventilation of the individual before, during, and following exercise by use of a bicycle erdometer. Plates were taken of the chest at maximum inspiration and expiration, and the total area of the lung fields was measured on the films; the anterior-posterior diameter of the chest was also measured. This permitted computation of the radiological volume of the chest, which equals the anterior-posterior diameter times the area. Erdometer readings were taken for groups of average miners, 20 to 30 years of age, at levels of 300 kgm. per min. and 600 kgm. per min. B. found that the volume of actual pulmonary ventilation could be predicted by use of the formula for the radiological volume of the chest. In such instances, the predicted pulmonary ventilation agreed fairly closely with the observed pulmonary ventilation. Four cases in this series are described. Ratios alone are insufficient for measuring disability; exercise reaction is also needed. K.R.

Dry-type air filters. E. KUNDIG. *Southern Power & Ind.*, **59**, 70–71 (1941).—K. describes air filters which depend upon sifting the dust. A woven textile material and a felt are the most commonly used media, and their efficiency depends primarily upon the density. An all-wool felt was found to be the best medium, as it is dense and yet does not offer the resistance of a woven material. Variations in air velocity do not affect the cleaning efficiency appreciably as long as the maximum velocity is limited to about 50 ft. per min. With a good dry-type filter it is possible to obtain a cleaning efficiency of 95% and higher for dust particles less than 2 microns in size. Individual filters and typical installations are illustrated. F.S.M.

Dust hazards in ceramic whiteware industry. L. M. MERRITT. *Ohio Industrial Commission Monitor*, **13**, 163–66 (Nov., 1940).—The Ohio Industrial Commission allowed 42 silicosis claims in the ceramic whiteware industry between August 1, 1937, and October 1, 1940, including 21 in china and tableware plants, 17 in floor and wall tile plants, and 3 in electrical porcelain plants. In the remaining division, the sanitary plants, no claim has been allowed, but a potential hazard exists. Steps in the manufacture of whiteware are described, with consideration of the hazards and recommendations for each operation. The principal raw materials are clay of several types, feldspar, flint, talc, and pyrophyllite. The flint is practically all free silica. Some china clays, feldspar, and pyrophyllite contain small amounts of free silica. A whiteware body contains from 10 to 40% flint. In the three methods of compounding the ingredients of the clay body, viz., blunging, ball milling, and dry mixing, hazardous dusts are produced only before the body is wetted. The ingredients are unloaded from railroad cars, and smaller amounts are weighed and mixed. Many plants buy flint, the most hazardous ingredient, with 2% moisture, which helps prevent dust but does not necessarily reduce the hazard to within safe limits. M. recommends that, in all cases, the bins and weigh-car track be isolated from the filter-press room by a dust-tight wall and that respirators be worn at all times in the bin and weigh-car area. After removal of the water from the slip by filter-pressing, the material in various processes is sufficiently dry to cause dust. Recommendations vary according to the process and include dust-tight enclosures, exhaust ventilation, and respirators. Sand is used in some of the firing processes, and sanding should be done inside a cabinet with the workmen outside, with an air movement of not less than 100 ft. per min. face velocity. Most glazes contain flint and lead, and, when they are applied by spraying, an air movement of 300 ft. per min. in the spray cabinet is often necessary. When cadmium and selenium salts are sprayed for decoration, an air movement of not less than 100 ft. per min. at the face should be provided. In general, good housekeeping and removal of the dust at its source are essential. See *Ceram. Abs.*, **20** [7] 185 (1941). F.S.M.

Dust in the stone and clay industries (general survey). HANS LEHMANN. *Ber. Deut. Keram. Ges.*, **21** [10] 412–16 (1940).—Dust is a problem, especially in regard to cleanliness and the health of the workers. In some cases attemps are made to utilize the dust. In the ceramic industry in turning and casting, it is impossible to prevent material from falling on the floor, drying, and turning to dust. According to Anselm (*Zement*, **28**, 15, 30 (1939)), in 1938 15 million tons of cement were produced in Germany, of which 14%, or 2.1 million tons, was dust. Of this dust, 76% was recovered, but 10% could not be recovered by the best methods now available. Where dust cannot be avoided, dust masks should be used. Discussion of silicosis is necessary as technical developments are not ended; plans must be made for the future. Thousands of men have worked for years under severe conditions, and only a doctor can determine the ability of a given worker to endure certain working conditions. W.H.H.

Effect of short rest pauses in standing and sitting position on the efficiency of muscular work. ERNST SIMONSON AND NORBERT ENZER. *Jour. Ind. Hyg. & Toxicol.*, **23**, 106–11 (March, 1941). F.S.M.

Grammer of Witwatersrand silicosis. A. MAVROGORDATO. *Jour. Chem. Met. Mining Soc. S. Africa*, **40** [10] 326–41 (1940).—M. states that a solution of soluble SiO_2 in the body fluids does not act as a tissue poison or form scars in the lungs. He summarizes the results of 25 years research on Witwatersrand mine silicosis as follows: (1) only particles $< 5\mu$ produce silicosis; (2) the minimum quantity of this fine dust necessary to produce fibrosis is approximately 1.5 to 2.0 gm., and this amount is accumulated quickly or slowly according to its concentration in the air; (3) approximately one half of the Witwatersrand dust of fibrosis-producing size that is inhaled from day to day is retained and accumulated in the lungs; (4) gravimetric samples of Witwatersrand mine air-borne dust taken over a period of 20 years show that there is a definite relation between the mass of air-borne dust and its rate of accumulation in the lungs; (5) the proportion of dust of fibrosis-producing size is from 20 to 50% by weight of the total air-borne dust; (6) the number and size of the particles making up this mass of dust is of no particular significance, and the mass distribution of the dust is of greater importance than the size frequency; (7) it is tentatively suggested that, with air-borne dust of effective fibrosis-producing size at a concentration not exceeding 0.15 mgm. per cu. m., the average miner would be safe for 7000 shifts as far as simple silicosis is concerned. This should correspond, under present conditions, to a total air-borne dust of 0.6 to 0.7 mgm. per cu. m. which is often found. Illustrated. L.W.V.

Historical milestones in occupational medicine and surgery. A. H. WHITTAKER AND DAVID J. SOBIN. *Ind. Med.*, **10** [5] 203–205 (1941).—The first printed thesis dealing with occupational health was written in 1473 by Ulrich Ellenbog, a Doctor of Medicine and Physician to the Bishop and Chapter of Augsburg Cathedral from 1470 to 1478. It concerned the occupational hazards to goldsmiths and other metal workers from breathing in fumes. K.R.

Importance and aims of the professional training given in the ceramic school in Bechyně. JOSEF ŠIMÁK. *Zprávy České keram. společnosti*, **16** [1–2] 35–38 (1939).—In this school knowledge of machines and furnaces and their care in the preparation and working of raw materials is taught. An interest in ceramic work, attentiveness, and application are cultivated in the student. M.V.C.

Industrial poisons—physiological and clinical. G. H. GEHRMANN. *Conn. Med. Jour.*, **4**, 3–4 (Jan., 1940).—G., medical director of the E. I. du Pont de Nemours & Co., states that, of the hundreds of thousands of compounds utilized daily in industry, it is now felt that all are toxic in some degree. Diagnosis, treatment, and prevention demand knowledge of the working conditions of the individual's present and also his prior employment. Topics treated are as follows: (1) heat prostration and heat cramps, their mechanism of occurrence, predisposing factors, and treatment and the hygiene required; (2) lead intoxication; (3) irritant cases, i.e., nitrous fumes; and (4) aniline and dyestuffs. K.R.

Investigations comparing the danger to the lungs from natural and artificial grindstones in grinding shops. GAERTNER. *Arbeitsschutz*, pp. 245–48 (1940).—Experiments were conducted in which rabbits inhaled dust produced by crushing two natural and two artificial grindstones. One of the latter was compounded of minerals and the other of ceramic compounds containing 25% insoluble silicic acid. No silicotic changes were produced by the dusts but only slight connective tissue and capillary proliferation. The dust of the natural grindstones, containing 93.2 and 74.2% quartz, produced typical silicotic nodules. A fuller report is being prepared. F.S.M.

Mineralogical investigations on silicosis. J. H. HELLMERS. *Fortschr. Mineral., Krist., & Petrog.*, **23**, CXXVIII-CXXIX (1939).—Granite and quartz porphyry are dangerous, but basic rocks are not. Rocks which are rich in quartz and poor in lime, e.g., sandstones, siliceous rocks, roofing slates, clay slates, and shales, may cause silicosis. Methods of determining the mineralogical composition of the dust are described. See *Ceram. Abs.*, **18** [5] 141 (1939). W.N.

Modified eyepiece micrometer for use in dust counting. W. B. HARRIS. *Jour. Ind. Hyg. & Toxicol.*, **23**, 148–50 (April, 1941).—H. discusses the disadvantages of the method of dust counting with the Whipple disk and of the various modifications of the method. He uses a modified method in which glass-wool fibers are attached to the ocular diaphragm of the eyepiece tube, 1 mm. apart in each direction, producing a grid of 25 squares in the center. This is calibrated against a stage micrometer as is done with the Whipple disk. This device does not require cleaning and has been successfully used for over a year. F.S.M.

New regulation regarding the manufacture of glass and the grinding, etching, painting, glass container, and related industries, dated Sept. 13, 1940. ANON. *Arbeitsschutz*, p. 263 (1940).—The German regulations prescribe that X-ray examinations be made of all workers employed in rooms where glass containers or refractory materials are produced or where sandblasting is conducted. The examinations are repeated every second year. All persons engaged in producing lead-containing mixtures or using lead colors must be examined at least every 6 months. F.S.M.

No exposure to silica in glass plant. ANON. *Ohio Industrial Commission Monitor*, **14**, 27 (Feb., 1941).—The claimant applied for an award from the Occupational Disease Fund, alleging that he was forced to quit work on May 31, 1940, as a result of getting glass in his lungs in the course of his employment. The claims reviewer reported that the claimant entered the service of the employer in January, 1937, and worked until May, 1940, when he was compelled to quit work. He was a laborer in the plant which has a glass processor for the preparation of glass sheets for shipment and sale. He did not do any of the work of grinding or polishing, and evidence showed that there was an infinitesimal quantity of free silica in the air of the plant and no more dust than in the average plant. Medical proof of record showed that the claimant's disability was caused by pneumonia and that silica was not a factor. There was no proof that the claimant had any injurious exposure to silicon dioxide either before or after the date of the Silicosis Amendment. The medical department disapproved the claim, and the Commission ordered that it be denied. F.S.M.

Phagocytosis of foreign material in the lung. O. H. ROBERTSON. *Physiol. Rev.*, **21**, 112–39 (Jan., 1941).—R. reviews the modes of entrance, distribution, and disposition of foreign material in the respiratory tract. Inasmuch as the lung appears to act as a filter for foreign material injected intravenously, it has been suggested that the pulmonary capillary endothelium carries on phagocytic activity. The evidence, however, is to the contrary. This is also true of the cells lining the tracheobronchial tree. 155 references. F.S.M.

Pneumoconiosis. A. J. LANZA. *Minnesota Med.*, **23**, 776–81 (Nov., 1940).—L. briefly discusses the history of the recognition of pneumoconiosis, its relation to exposure, its diagnosis, and the unsolved problems, including its relation to tuberculosis and the effects of mixed dusts. F.S.M.

Pneumoconiosis due to enamel dusts. E. GAUBATZ. *Fortschr. Gebiete Röntgenstrahlen*, **61** [4] 233–40 (1940).—G. considers the pneumoconiosis occasioned through silicates, especially talc, and describes the technique of enameling. Four cases of enamel silicosis are reported, in which the exposure time was 10 to 13 years. Differentiation of the Roentgen films of these four cases led to the conclusion that a more or less strongly impregnated silicosis in combination with silicatosis derived from enamel dusts was present. The changes were not extensive so that no compensation, according to the Third Ordinance of the Reich, December 16, 1936, was yet called for. Further observations were made during the next year to determine whether the pulmonary changes were advancing. 7 references. K.R.

Problems of technical school education. BERDEL. *Ber. Deut. Keram. Ges.*, **22** [1] 2–7 (1941).—Early ceramic schools, founded 50 to 70 years ago, placed the emphasis on turning, forming, modeling, and painting. It was considered revolutionary when Pukall introduced chemistry and physics in 1897. The Seger formula for calculating glazes was given such a prominent place in instruction that some regarded it as a form of magic by which any problem occurring in practice could be solved by calculation. The requirements of an education in ceramics have so increased in the last 30 years that, regardless of what efforts are made, it has become very difficult to keep the students informed on the great changes in scientific and technical ceramics. B. suggests three directions in which instruction should be improved: useful training of apprentices beyond what can be learned in an ordinary trade school, further training of older selected workers as foremen, and establishment of special courses and clubs for employees outside of working hours, with evening lectures and experiments. W.H.H.

Report of the Committee on Standards. JOHN W. WHITTEMORE, *Chairman*. *Bull. Amer. Ceram. Soc.*, **20** [6] 218–20 (1941).

Research and trade promotion. F. P. GASS. Presented at meeting of Glass Container Assn., May, 1941; abstracted in *Amer. Glass Rev.*, **60** [35] 13–14 (1941). A.P.

Routine chest X-ray examination of recruits: survey of results. W. A. JONES. *Can. Med. Assn. Jour.*, **43**, 213 (1940).—J. presents the results, up to April, 1940, of a

health survey which had as its purpose the discovery of concealed thoracic disease among men otherwise considered eligible for military service. As a result of this examination, 1.5% were rejected. Seventeen cases of silicosis were discovered. Follow-up work in a district believed to be free of this disease resulted in the discovery of six additional cases. F.S.M.

Severe pneumoconiosis caused by inhalation of fuller's earth. W. D. McNALLY AND I. S. TROSTLER. *Jour. Ind. Hyg. & Toxicol.*, **23** [3] 118–26 (1941).—Fuller's earth is a silicate, but although silicatosis is caused by the inhalation of silicates, the inroads of fuller's earth dusts shown on films of the lungs cause the authors to use the safer, more general term, pneumoconiosis. The findings of Badham, an Australian physician (1927) and of E. L. Middleton ("Silicosis . . . IV," *Ceram. Abs.*, **20** [4] 108 (1941)) are given. In a fuller's earth plant at Olmstead, Ill., dust counts were made and studied by McNally in 1934; the manufacturing processes used are described, and the complicated chemical composition of fuller's earth dusts is given. The term, fuller's earth, is applied to any clay having a high capacity for decolorizing animal, vegetable, or mineral fats and oils. Most of the product mined in Illinois is found in Pulaski Co. in the extreme south of the state. The material is dug from the ground with power shovels and transferred to the plant, where it is dried, ground, and bagged. According to the Illinois State Geological Survey, its chemical composition, given in the order of abundance, at the Olmstead plant includes montmorillonite, identified by its optical data, chemical analysis, dehydration curves, and X-ray data, as the dominant and characteristic mineral. It is a silicate having the formula $(Mg, Ca)O \cdot Al_2O_3 \cdot 5SiO_2 \cdot (5\text{–}8)H_2O$. It consists of SiO_2 48.60 to 60.78, Al_2O_3 13.83, and Fe_2O_3 4.36% and 8 other oxides of relatively low percentage value. Its quartz has a maximum diameter of 0.12 mm., flakes of muscovite 1 to 2%, glauconite 1 to 2%, and a total rock mass of 1 to 2%. Amorphous silica is 1% or less of the total. Twelve other minerals are found irregularly scattered in angular, unaltered grains, 0.06 mm. in size. In 1939, 5 years after McNally's dust counts, 49 men from the plant with a major dust exposure of over 8 years were examined; the procedure and findings are all tabulated and discussed. The amount of fuller's earth in the lungs of the men examined is evaluated in comparison with known and equal thicknesses of aluminum, the X-ray procedure being detailed. It was ascertained that a layer of the fuller's earth loosely packed has almost the same density and radiopacity as those for the same thickness of aluminum, the density or amount of extra shadows seen in the films being possible to estimate if made with the same technique. Some experimental data were derived from guinea pigs, and the procedure is presented in detail. One-half the animals died of fibrosis; several died of tuberculosis, fuller's earth dusts evidently not affording protection against its development. Seven case histories of plant workers are presented, one in detail; for the other six, descriptions are given of the pulmonary conditions as shown in their roentgenograms. Examination of 49 men working with fuller's earth showed pulmonary changes. As these men had worked at different jobs during the course of their employment and were exposed to dusts of varying composition, the effect of age or time in the development of the pneumoconioses involved is impossible to evaluate. One man, aged 59, exposed for 16 years, showed little lung pathology; another, aged 46, employed for the same length of time, had marked and incapacitating pneumoconiotic conditions. Inhalation of fuller's earth dust causes symptoms similar to those seen in silicosis. Because of the extensive use of fuller's earth in bleaching fats and oils, industrial physicians should strive to reduce to a minimum the dust hazard from this source. K.R.

Sickness among industrial workers. WILLIAM M. GAFAFER. *Amer. Jour. Pub. Health*, **31** [5] 443 (1941).—G. gives the results of a study made to correlate both the frequency and the duration of disability with the age of the employee. **Discussion.** RICHARD D. MUDD. *Ibid.*, p. 447.—The age-group of 31 to 40 years was shown to produce the greatest percentage of the total disability. B.C.R.

Silicosis in Ohio in 1940. ANON. *Ohio Industrial Commission Monitor*, **14** [Jan.] 16; [Feb.] 30 (1941).—Although incidence of silicosis at large may be on the decrease due to the knowledge of the disease gained during the past twenty years, more cases came to the attention of the Ohio Industrial Commission in 1940 than in any year since the disease became compensable in 1937. During the first 29 months of operation of the law, 330 claims were filed; of these, 111 were allowed and 165 were rejected, approximately a 40% allowance. In 1940, 249 claims were filed, of which 83 were allowed and 113 were rejected, an allowance of about 42%. F.S.M.

Silicosis of porcelain workers. DE LEOBARDY. *Med. du Travail*, **11** [1] 37–38 (1939).—A study made by Gadjusson and Fleiming Moller (Denmark) on the silicosis of workers in porcelain plants is recorded. Of the 951 industrial workers concerned in this study, 798 were radiographed. Silicosis was found to be extremely prevalent among them. The disease had a relatively slow evolution but was constantly progressing. In the radiographs it was manifested by peribronchial and perivascular nodules, relatively mild in type, with a tendency to interstitial lesions. Eventually, of every 100 workers who had worked over 50 years, the entire 100 would have severe silicosis (third stage). Although all the workers examined during this inquiry were capable of working, the silicotic subjects showed a very high respiratory death rate, higher than that of subjects who were receiving compensation for silicosis. More than half the deaths were due to pulmonary infection. While the number of those complaining of dyspnea and of coughs was quite large, tubercular infection was a rare complication. Among those attacked by tuberculosis, the severe forms were not observed. K.R.

Silicosis problem. P. F. MØLLER. *Acta Radiol.*, **21**, 571–76 (Dec. 31, 1940).—M. believes that the X-ray diagnosis of tuberculosis complicating silicosis is made too often and that this results from lack of appreciation of the pathology of simple silicosis. In his opinion, third-degree silicosis may completely simulate the X-ray changes seen with advanced tuberculosis. With silicosis there is often advanced emphysema with blebs which may appear as cavities in the X-ray plate. F.S.M.

Silicotic nodule in human and experimental silicosis (a comparative study). I. H. BELT, A. A. FERRIS, AND E. J. KING. *Jour. Path. & Bact.*, **51**, 263–67 (Sept., 1940).—The authors made a comparative study of silicotic lesions in man and in rats, the latter being produced by single intratracheal injection of silica ranging from 0.8 to 5 microns. The zone of fibrous tissue practically without silica particles (redundant fibrous encapsulization) is stressed as an important difference between silicosis as seen in man and that in experimental animals in which the condition was absent. Differences in the character and pattern of the fibers are pointed out. The possibility that, in man, the lesion may be complicated by infection is considered. F.S.M.

Visual efficiency in industry. A. M. CULLER. *Jour. Amer. Med. Assn.*, **116**, 1349–55 (1941).—A record of visual acuity, with and without glasses, of all industrial workers is important. The establishment of minimum standards of visual efficiency for various occupations is necessary. C. urges that the American Medical Assn. appoint a committee for the study of this problem. This committee may also aid in the correction of faulty legislation. The sequelae of eye injuries is discussed, some of which may make manifest latent refractive errors. The conservation of eyesight in industry depends upon (1) testing the eyesight of applicants, (2) examination of the eyes of those having defective vision, (3) proper placement of workers with defective vision, (4) proper illumination without glare, (5) education of workers regarding hazards to the eye, (6) protection of eyes in hazardous jobs, and (7) prompt treatment of ocular injuries. F.S.M.

Workmen's compensation diagnosis of hernia. A. L. SORESI. *Med. Record*, **153**, 77–81, 102–103 (Feb. 3, 1941).

—The compensability of hernia is ascertained from the viewpoints of (1) whether the workman is properly insured and entitled to compensation treatment, (2) whether the hernia really exists, and (3) whether there is a definite causal relationship. With regard to the first point, S. recommends that (1) a card be issued to the workman stating that he is properly insured and (2) a new card or renewal notice be issued when the policy is renewed. The difficulties in diagnosis in the early stages and the determination of causal relationship are discussed. Cases of faulty diagnosis are cited, mostly arising from lack of training on the part of the examining physician or from poor examination. Rules for proper examination are given. Accurate history is necessary although often difficult to obtain. The "hernia racket" could be smashed (1) if the causal relationship were based on purely scientific grounds and not on histories which are largely false, (2) if the question of compensability were established absolutely before an operation, without unwarranted delays and handicaps of all kinds, and (3) if the diagnosis of initial hernia were made only by competent surgeons.

F.S.M.

Workmen's compensation in Great Britain. ANON. *Monthly Labor Rev.*, **51**, 888–91 (Oct., 1940).—Compensation payments for all disabled workers and their wives and children are increased by the Workmen's Compensation Act of 1940. Workers suffering from silicosis and certain other industrial diseases also share in the increasing benefits. Up to the end of 1938, compensation had been paid for 7504 cases of silicosis since this disease became compensable. Payments were made in 2739 cases in 1938. In 8 years, compensation was paid for 257 cases of asbestosis of which 4 fatal cases and 54 disablement cases occurred in 1938. Dermatitis increased from 270 cases in 1919 to 3489 in 1938. Skin ailments occur in a variety of industries but chiefly among bakers and confectioners, dye workers, French polishers, and engineers. F.S.M.

X-ray examination of the structure of dust as a method of medical examination. GAERTNER. *Arbeitsschutz*, pp. 193–95 (1940).—The X-ray examination of air-borne dust and dust in the lung is described. G. found no quartz in silicotic lungs of china-clay workers who handled kaolin and sillimanite. He concludes that these substances are also able to produce silicosis. See "Roentgen . . .," *Ceram. Abs.*, **20** [2] 59 (1941). F.S.M.

X-ray tests of men in a series in the stone and clay industries, with special reference to diseases of the lungs. H. BUCKUP. *Ber. Deut. Keram. Ges.*, **21** [11] 441–59 (1940).—It has long been known that different kinds of dust have different effects and that silicosis causes impaired circulation and tuberculosis. B. studied silicosis especially in the ceramic and porcelain industries. In 1929, silicosis was recognized as an occupational disease. By the law of 1936, disease of the lungs due to dust is cause for compensation when it has reached a certain stage. A large-scale investigation was begun in the fall of 1939 and finished in June, 1940, using the X-ray method. In this method, the image, instead of being viewed by the physician directly, as with the fluoroscope, is photographed by a small camera using a cinematograph film usually 24 x 32 mm. The advantages of this method are speed and low cost. As many as 1500 exposures have been made in a day. The X-ray apparatus is installed in a vehicle and taken to the workers, so that they do not lose time coming to the X-ray institute. Experience showed that about 20 exposures a day could be finished at the institute in addition to the regular work. Obviously, more can be seen on a larger picture, but, in general, the small pictures are adequate for the detection of the start of tuberculosis in stages II and III but not sooner. It is difficult, however, to detect tuberculosis at the very beginning by any means. The X-ray method cannot be used to detect the start of silicosis so that those who are endangered can be transferred to work more suitable for them. In the 1939 to 1940 investigation, 13,428 pictures were taken at 49 plants. The results show a smaller percentage of workers with diseases of the lungs than that shown by previous investigations. The results show that the danger of silicosis in the clay pits is not inconsiderable, silicosis being found in 12.2% of the cases, which is about the same percentage as that found for the whiteware and porcelain plants. The question of what to do with those found to have tuberculosis and silicosis remains. Old cases of tuberculosis may be permitted to continue at their work as it has not been shown that susceptibility to tuberculosis indicates a susceptibility to silicosis. Young men who show tuberculosis should be removed from work where they are exposed to dust. Men over 45 may be allowed to continue their work. X-ray surveys should be made at intervals of about 5 years.

W.H.H.

BOOKS AND SEPARATE PUBLICATIONS

Industrial Research Laboratories of the United States. CALLIE HULL, compiler. *Bull. Nat. Research Council*, No. 104, 372 pp. (Dec., 1940). 7th ed. Price $3.50.—This directory contains information concerning 2264 industrial concerns which maintain one or more research laboratories. With certain subtractions, it includes 469 more concerns than were listed in the sixth edition issued in December, 1938. In most cases, the following items are given for the laboratories listed: (1) address of the laboratory, (2) name of the president of the corporation, (3) name of the research director, (4) classification and number of members of the research staff, (5) research activities, and (6) cooperative research and laboratory publications when the company sponsors these enterprises. Indexes to the directory cover the geographical distribution of laboratories, the personnel, and the subject of the research activities. The personnel index includes the names of about 6900 research workers. F.J.Z.

Nontoxicity of Cement Dust. R. B. FORTUIN. *Penna. Dept. Labor & Ind., Safe Practice Bull.*, No. 82, 10 pp. (March, 1941).

Photodynamic Action and Diseases Caused by Light. HAROLD FRANCIS BLUM. American Chemical Society Monograph Series, No. 85. Reinhold Publishing Corp., New York, 1941. 310 pp. Price $6.00.—The relationship between photodynamic action and the diseases caused by light is discussed. B. reviews the extensive literature and all viewpoints and attempts a synthesis of various phases by beginning with certain fundamental physical and chemical principles. The historical background, elementary principles, and general biological effects of radiation are discussed. The general aspects of photodynamic action, including the mechanism, role of oxygen, varieties, effectiveness, and the photobiological processes, are dealt with. The diseases caused by light in domestic animals and those produced in man are considered. Of the latter, the most common is the phenomenon commonly called sunburn. Although the antirachitic spectrum lies in the same general region as the sunburn spectrum, this process has no relationship to sunburn. The pigmentation of negro skin which offers considerable protection against sunburn radiation as it is distributed in the more superficial layers is in contrast to the pigment of the white races which is found principally in the basal cells and can offer little protection.

Abnormal responses to blue and violet light (*urticaria solare*) are discussed at length. The photosensitizing action of porphyrins which was first suggested in 1898 is dealt with. The experimental evidence seems to support the contention that porphyrins play little if any part in producing lesions in the condition which is most commonly attributed to such action, viz., *hydroa vacciniforme* of Bazin. There is, however, little doubt that the porphyrins act as photosensitizers in man. The relationship of skin cancer and the sunburn spectrum are considered, and a review of the evidence on *xeroderma pigmentosum* is presented. Substances which produce photosensitization on coming in contact with the skin are given, including plants, figs, perfume, green soap, and coal-tar and petroleum products. B. considers substances which produce photosensitization when applied internally and a miscellaneous group of diseases attributed to light. The part played by light in pellagra, lupus erythematosus, diseases of the eye,

jaundice, etc., is discussed. An extensive bibliography and author and subject indexes are included. F.S.M.

Pulmonary Diseases in the Mining Industry. R. R. SAYERS. *U. S. Bur. Mines Information Circ.*, No. 7146, 26 pp. Free.—S. discusses diseases encountered in mining, viz., bronchitis, influenza, pneumonia, tuberculosis, anthracosilicosis, and silicosis, and their prevention by dust control. R.A.H.

Recommended Good Safety Practices for the Protection of Workers in Foundries. AMERICAN FOUNDRYMEN'S ASSN., INDUSTRIAL HYGIENE CODES COMMITTEE. Amer. Foundrymen's Assn., Chicago, 1940. 69 pp. Price $2.50. F.S.M.

Safe Practice in the Manufacture and Uses of Fiber Glass. T. S. ROGERS. *Penna. Dept. Labor & Ind., Safe Practice Bull.*, No. 58, 10 pp. (Feb., 1940).—The processes of making the various forms of fiber glass, including loose heat-insulating material, "blankets" for boilers, etc., filters, felts, and textiles are described, together with the various uses of the material. In making fiber glass, the eyes should be protected under certain conditions of exposure. No cases of injury to throat or lungs are known. Gloves are not usually necessary in handling the material, and thorough washing with soap and water removes particles from the skin and relieves prickly sensations. F.S.M.

Autumn Meetings Schedule

ENAMEL: Porcelain Enamel Institute Forum, Ohio State University, Columbus, Ohio, October 8–10.

GLASS: Hotel Conneaut, Conneaut Lake Park, Pennsylvania, September 12–13.

MATERIALS & EQUIPMENT and WHITE WARES: Summit Hotel, Uniontown, Pennsylvania, September 19–20.

REFRACTORIES: Granville Inn, Granville, Ohio, September 5–6.

STRUCTURAL CLAY PRODUCTS with STRUCTURAL CLAY PRODUCTS INSTITUTE: Mayflower Hotel, Washington, D. C., November 4–6.

Plan to attend one or several of these Meetings. The time and money spent are negligible compared with the benefits received through contacts made with your fellow ceramists.

The programs for the Division Meetings will be published in The Bulletin.

THE AMERICAN CERAMIC SOCIETY, INC.

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